ADOPTING SUSTAINABILITY INTO THE MECHANICAL ENGINEERING DESIGN PROCESS: ORGANIZATIONAL CHANGE THROUGH A LENS OF STRUCTURATION

by

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ABSTRACT

Global climate change presents large-scale challenges to humanity. Vast, urgent, and creative changes are necessary to reduce impending consequences. Although technology cannot be viewed as a cure all, changes in energy sourcing, manufacturing, and industrial emissions are necessary to reduce carbon in the atmosphere. This dissertation focuses on processes of organizational change as a department of mechanical engineering at a research university struggles to train students to design in a more sustainable way. Thus, changes in design processes portend material consequences for the environment (e.g., less emissions, waste, and resource extraction). This qualitative study helps organizational communication scholars and students better understand the challenges of socialization at a transformational time in our collective history. Structuration theory offers a lens through which to identify contradictions within macro-, mid-, and organizational levels as well as a platform for further categorizing contradictions with primary, secondary, tertiary, and quaternary classification systems. Additionally, it allows for a discussion of how these levels influence each other.

This study also advances theory by pinpointing contradictions using Canary's structurating activity theory; investigating how structuration helps researchers explore socialization in more exhaustive ways; and combining the identification of contradictions with identifying resources as a simple yet effective approach to analyzing organizational change. Based on these findings, a series of interventions and resources are presented. In

the face of global climate change, organizational procedures necessitate rapid change. As such, this dissertation offers a theoretically-driven change model that can be used to incorporate a sustainability ethos into the design process.

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PROLOGUE

Changes in technology can make a significant difference in environmental conflict. Snowmobiles in Yellowstone National Park offer a case study of how new technology can make a dramatic difference in environmental issues (Shogren, 1013). For over 15 years environmentalists and those who enjoy snowmobiling have been at odds with each other about appropriate use of snowmobiles inside of the park in the winter. The issue has been tied up in court, conflict resolution working groups, and tension-filled community meetings. Until the mid-1990s recreational users and guiding operations toured the park on snowmobiles. Over 80, 000 machines toured the park every winter season and environmentalists argued that the noise and pollution were at odds with the mission of the national park. Anecdotally, the exhaust from the machines would create a haze of pollution that made breathing difficult throughout the winter. The contentious issue raged as various policies were implemented. Over time policies ranged from no snowmobiles in the park to 950 machines per day offered through touring operations. It seemed that these two groups would never find compromise.

With new engineering technologies, snowmobiles are now quieter and produce fewer emissions. A resolution that made all parties happy was achieved in the fall of 2013. This resolution was achievable because of new technology. This case study illustrates that, although technology will not be the single salvation for environmental issues, it can play a part in creating solutions. With this in mind, please read the following study considering that a change in communication about the design process can have material consequences on the environment. Although the Yellowstone issue involved lawyers, mediators, and activists, changes in technology ultimately solved it. Yet, this possibility for new and more sustainable technologies has not become a cornerstone value of the mechanical engineering profession. This project investigates the process of change in the socialization of new mechanical engineers.

CHAPTER 1

INTRODUCTION

Global climate change offers challenges to humanity that we have not seen before. The National Climate Assessment Development Advisory Committee released a 2013 Climate Assessment Report for public review that states that global climate change is occurring, is human caused, and is going to have profound effects on all life on earth. The report outlines increased CO_2 in the atmosphere, increased temperatures, extreme weather events, rising sea levels, and increased acidity in oceans. Habitats of animals, plants, and humans will be affected, with increased flooding, wildfires, and temperatures. Human health will be impacted with quality of water, heatstroke, loss of food sources, and distorted rhythms of nature. Ashford (2004) states, “The environmental problems include toxic pollution, climate change, resource depletion, and problems related to the loss of biodiversity and ecosystem integrity” (p. 240). Life as humans have known it will change dramatically.

Katharine Hayhoe, Director of the Climate Science Center at Texas Tech University said, “This is no longer a future issue. It's an issue that is staring us in the face today” (Borenstien, 2013, p. 1). Hoffert et al. (2002) state that to accomplish this goal we need “revolutionary changes in the technology of energy production, distribution, storage, and conversion” (p. 981). The National Climate Assessment Development

Advisory Committee (2013) states that humans have the choice either to lower emissions and decrease the impacts of global climate change or to adapt to the new living conditions. Many feel that the key to both mitigating the effects and to adapting will be technology. According to Dincer and Rosen (1999) energy efficiencies gained through new technologies will be necessary to lessen particulates in the atmosphere.

Although technology is widely touted as the solution to global climate change, the current culture of engineering is not intensely focused on finding solutions to our fossil fuel dilemma. Some engineers are working on designing new technologies with an emphasis on sustainability, but they are currently the minority. Visionaries in engineering leadership understand that a cultural change in engineering education is important to prepare future engineers for their careers. However, existing literature suggests that this effort has thus far failed for the most part. An exemplar of this dilemma is Mountain State University mechanical engineering program, in which there are some faculty and students interested in and focusing on sustainable design while most are not, and change efforts have not yielded the desired change. There is a pressing need to better understand how change might be addressed more successfully.

Sustainability Education in the Mechanical Engineering Program

As a CLEAR (Communication, Leadership, Ethics, and Research) instructor at Mountain State University College of Engineering, I had the privilege to observe engineering classes ranging from 1st year to graduate level. In my 3 years of participation in this learning community, I noticed that there is little focus on sustainable design taught in classes or communicated in department culture. Additionally, students are unclear about what sustainability is. In the spring 2012 semester, students in the Introduction to

Energy System Design II class were given an assignment to research an example of sustainable engineering. At the end of the semester the students were asked about their level of familiarity with sustainability and renewable energy sources. With 1 indicating unfamiliar and 5 extremely familiar, the average class score was 2.84/5.00. I asked 259 freshman, sophomore, and senior engineering students the top five things they considered when designing a product and only 15/259 – or less than 6% – said sustainability was a lead priority when designing. Additionally, when the same group was asked to define triple bottom line (a business model that considers the social, environmental, and financial aspects of the bottom line) (Elkington, 1999) and the "five Rs" of sustainable design (reduce, reuse, recycle, replace, and reinvent), less than a third of those surveyed knew what these concepts were (Blevins & Burian, 2012). These answers indicate that an investigation of sustainability instruction in mechanical engineering classes could offer some insights into how new engineers are socialized.

Mechanical engineering stands at the crux of this conflict as this discipline is at the forefront of designing cars, airplanes, robotics, machining processes, and other technologies that rely on combustible motors, which contribute heavily to carbon output in the atmosphere. Additionally, mechanical engineers have the skills and knowledge to refocus design efforts into technologies such as sources of sustainable energy, new battery technology, and motors that do not expel carbon. Currently, this field is at a crossroads experiencing conflicting pressures. It is a discipline slow in changing and yet faced with increased demand to reduce carbon output—a contradiction that manifests throughout the professional training that occurs in university programs. Specifically, professors and students must deal with the conflict between training students in the skills and ideologies they will need to design sustainably in the future and simultaneously teaching professional skills and ideologies that have proven successful. This contradiction between the current beliefs and practices of the profession and the skills and ideologies needed for new design is ripe for exploration about organizational change and how to socialize new members while change is occurring. Although much existing socialization literature assumes that new professionals are socialized into relatively stable professions, the case of mechanical engineering poses a challenge to such assumptions. This case, then, is particularly significant for its implications for climate change as well as for its potential to complicate our understanding of successful (and unsuccessful) professional socialization.

This is an historically significant moment in which the policies, cultural assumptions, and rewards inherent in the system of mechanical engineering are being challenged by the new necessities of global climate change. The current discourse around climate change and society is replete with contradictions. Society wants both the conveniences and efficiencies that come with our current way of life and a way to sustain these conveniences. We are facing a contradiction: We behave as if resources will go on forever; however, we know better. For these reasons, the mechanical engineering program at Mountain State University offers an exemplary case study as those involved struggle with the professional socialization process that occurs through university classes. Canary (2010a) issues a challenge to further investigate contradictions in the field of organizational communication. The goal of this project is to understand how mechanical engineers are trained to think about sustainable design and to identify the contradictions that exist as these students are trained within the structures of the organization. The points where contradictions manifest themselves can be identified, and these points in turn will illuminate where the tensions make fault lines at which change is primed to occur.

A valuable theoretical lens through which to investigate contradiction is structuration as presented by Anthony Giddens (1984). This theory examines the relationship between agency and structure. The foundation of his theory rests on the idea that society cannot be examined from only a micro-lens, but must also be evaluated at the macro-level. Structures, or the rules and resources available to people, mold actions; however, such structures are created by human behavior and hence are constantly modified. Structures are created by agency and agency is influenced by structure, which causes constant tension between the two. Within these constantly changing structures are abstract contradictions that happen in every system; these contradictions cannot be resolved with simple solutions. It is when contradictions are recognized that change can begin to occur. The issue at hand is a good example of a set of contradictions that will require a deep system change. Identifying how this organization is experiencing and negotiating these contradictions may illuminate strategies that move beyond the struggle.

Specifically, this study analyzes the contradictions taking place as mechanical engineers are socialized into the field. When paying attention to current events, it seems that with the onset of global climate change, the increased desire for renewable resources, and a need for new technologies, an investigation of the mechanical engineering program at Mountain State University serves as a useful case study. As this community navigates these large paradigm shifts, this study offers an exemplar of an organization in an important moment. Although scientists and activists are calling for a significant change to lessen carbon output, change has been slow to occur. This study offers an exploration of a specific nexus where contradictions and change are manifested socializing new members of an organization when the organization is in flux. Understanding this phenomenon theoretically and practically offers a new communicative perspective on contradictions as manifested and negotiated in the socialization process during organizational change.

The goal of this project is to recognize the points of contradiction that exist within the process of socializing mechanical engineers to be more focused on sustainable design. In this process I identify contradictions and how they are manifested and negotiated through communication. Detecting these points leads to an identification of where change could be most effective, with an ultimate aim of illuminating this challenging landscape for engineering departments. Before I start that, I want to introduce my positionality, so that my biases and assumptions will be clear.

Positionality

I believe that global climate change is occurring and will have a tremendous impact on people, animals, plants, and ecosystems on the planet. Mechanical engineers are responsible for building motorized vehicles, medical devices, machines, and manufacturing robots. All of these products are great contributors to CO_2 emissions, use raw materials and resources as they are built, and create waste when they are no longer useful. Because of this, knowing how sustainability is talked about in the mechanical engineering department is important. There will be material consequences to how future engineers approach the design process. I see the issue of global climate change as important to all citizens of the world.

It is a multidisciplinary problem that will take the knowledge and expertise of many scholars across multiple fields. Specifically, organizational communication scholars have a great deal of knowledge to offer about how organizations talk about sustainability and socialize their members to more greatly value ideas of sustainability, and how to enact organizational change. Changes in policy, behavior, and technology will occur through adjustments within existing organizations; institutions such as governments that enact and enforce regulations; industries that determine what products they design, manufacture and sell; and the educational systems that decide curriculum and how students will be socialized to perform their jobs. Mountain State University's Department of Mechanical Engineering is an organization within the greater institutions of commerce and education, institutions that influence the values, knowledge, ethics, and skills to be emphasized during a college education.

Societally, there is much talk about climate change and the consequences it is going to have on weather, people, and infrastructure. However, society on the whole is having trouble adapting to new policies, technologies, and behaviors that will help to mitigate climate change. Observing the difficulties involved in embracing change in this department could serve as a case study examining the difficulties in embracing a more sustainable way of living.

Additionally, I come to this study as an Anglo, middle class, heterosexual woman. I am aware that my feminine presence in a male-dominated site impacted this study. I approached this study as a humanities scholar venturing into a world of applied science understanding there are epistemological differences in how the disciplines understand knowledge. These attributes certainly had an impact on this study, some of which were my identity as a woman and an environmentalist and the fact that I had been the instructor for many of the participants. In addition to the attributes I could identify, there are some that I could not, and how they impacted the study is unknown to me. These differences led to the ability to identify and interpret this community's language.

Justification for the Case Study

The matter at hand in this problem is the intersection of the academic discipline of mechanical engineering—a tradition grounded in building cars, airplanes, and machines that are dependent on fossil fuels—and the issue of global climate change. For the purposes of this study the academic department was considered an organization. It qualifies as such because it meets commonly-accepted criteria. First, it is goal-oriented and second, it relies on coordinated actions in pursuing its goals (Barnard & Andrews, 1974). The Accrediting Board for Engineering and Technology (ABET), the body that develops standards for college engineering programs, requires that sustainability be addressed in engineering curricula ("ABET accreditation," 2013). Also, academic programs that have touted the importance of sustainable design are gaining a great deal of publicity and praise from the media and policymakers; however, Mountain State University's mechanical engineering program has not made the switch to an ethic of sustainability. In interviews, many participants noted that they had not thought about the leading role mechanical engineers have in adopting more sustainable practices. Although they had not thought of it, many stated that simply talking about it during the interview changed their perspective. They expressed enthusiasm and recognition of the value of exploring this topic.

Weick and Quinn (1999) observe that change is difficult because it implies that the job has not been done correctly, and thus it needs to be different. Because there is an underlying critique whenever change is suggested, the process is difficult. This difficulty is clear in the case of engineers' designs. It has been proven difficult to accept that climate change is connected to CO_2 output and adjust design principles and processes accordingly. Many of the machines and vehicles that dispense pollutants and carbon into the atmosphere result from mechanical engineering designs. By admitting that the design has to change, they must accept that the industry created the problem.

The purpose of this study is to impact the material consequences of design. How mechanical engineers understand the design process has an impact on how design is enacted. If Mountain State University trains mechanical engineers to be more sustainability-focused, those engineers will enter the workforce ready to approach design in a new way that could have positive impacts on carbon output. The first step to creating a change in the culture of the department is to identify where contradictions exist, so they may be addressed. This process of identifying the contradictions and assessing how they are managed will hopefully act as a diagnostic tool for identifying where and how change should be enacted. Second, every discipline has the opportunity to incorporate a more sustainable way of studying subject matter: The insights of this study may shed light on general dynamics faced within many disciplines preparing students to communicate about climate change in a new way. Last, there is an opportunity for theoretical development by viewing socialization through a structuration lens.

CHAPTER 2

LITERATURE REVIEW

To fully appreciate what is happening within the context of this case study the first task must be to gain an understanding of the concepts being investigated. In the next section of this study I develop an argument as to why structuration theory provides a suitable lens through which to investigate sustainability in mechanical engineering. I start with defining the concept of sustainability, a complex and multidefinitional term. This ambiguous concept needs to be defined and understood before exploring why it needs to be part of the socialization process. Next, I discuss mechanical engineering education and identify the strong call for the inclusion of sustainability into the design education process. Then, I identify some successes and challenges that engineering programs have encountered while changing curricula. Next, literature from socialization, organizational change, and structuration is presented. Finally, I will introduce the research questions that will guide this study.

Sustainability

The most commonly cited definition of sustainability was created by the Brundtland Commission report, which defined *sustainable development* as "development which meets needs of current generations without compromising the ability of future generations to meet their own needs" (1987, chapter 2, paragraph 1). This definition not singularly embraced, and so although the term *sustainability* is often used, the definition is imprecise. Peterson (1997) postulates this ambiguous definition expands the possibilities of what can be done under the name of sustainability. This can be an advantage or a challenge. Some view the ambiguous definition as a challenge to adopting sustainable practices because it carries so many connotations that some people dismiss the idea as soon as they hear it (Djordjevic & Cotton, 2011). The term *sustainable development* has been adopted by the United Nations as a method of development that focuses on environmental and socioeconomic needs. The concept has produced a great deal of contentious discussion because sustainability does not necessarily fit with growth and development. The need for sustainable development has been widely discussed as an unworkable concept. Because the Bruntland report left the definition purposely ambiguous it is not certain what it encompasses (Fenner, Ainger, Cruickshank, & Guthrie, 2005; Hopwood, Mellor, & O'Brien, 2005). This term illustrates a major contradiction in which engineering design processes are embedded. This macro-contradiction leads to other contradictions that surround the process of incorporating sustainability into the design process. Some of these include sustainability versus development, technology versus systems embeddedness, stability versus change, and barriers to change versus pressures to change. These contradictions surrounding sustainability in the engineering process create both confusion and opportunity as engineers struggle to incorporate sustainability into curricula.

The first step to understanding sustainability in the mechanical engineering department is to identify how they define and teach sustainability. Pappas and Pierrakos (2010) note that sustainable design practices in engineering have their roots in two engineering fields: green engineering, which focuses on designing to be more in tune with the earth; and environmental engineering, which has to do with cleaning up the effects that technology has had on the environment. Sustainable design "focuses on design that requires fewer natural resources, produces less (or no) waste, and reduces, reuses, or recycles waste products" (pp.1-2). One university defines sustainable design as having four components: technical, financial, environmental, and societal (Prins, Kander, Moore, Pappas, & Pierrakos, 2008). James Madison University defines environmental sustainability as:

> an approach to the engineering of processes, products, and structures which has, indefinitely, a less negative, neutral, or benign effect on all environmental systems. Sustainable engineering design tends to produce products and processes in which nature is not subject to continual 1) increases in the use of natural resources, 2) increases in goods produced by society, and 3) increases in waste products and effects of their degradation. (Pappas & Pierrakos, 2010, pp. F1C-1)

Scholz, Lang, Wiek, Walter, and Stauffacher (2006) offer that the definition of sustainability is composed of these three things: (a) making sure the system is maintainable (will not collapse); (b) allowing future generations to fulfill their needs as past generations have; and (c) ensuring that systems can correspond with each other. To the question of what makes something sustainable, Peet, Mulder and Bijma (2004) offer that the key to sustainability lies in changing the view of the designer so that thought is given to how the product will fit into society overall.

Because mechanical engineers are trained to work and to design in the business world, this study will use the triple bottom line concept introduced by John Elkington in the 1990s (Elkington, 1999). This definition of sustainable design is usually adopted because it considers the economic, social, and environmental implications of the product (Slaper & Hall, 2011). This conception of sustainability does not eliminate financial gain from the design and production of new products; it does, however, include the impact that the product will have on society and the environment. This definition is relevant in this case because mechanical engineers can operate with this definition and still focus on earning a profit, while also broadening the scope of design to include environmental aspects that previously have been ignored or considered victims of externalities. To underscore how sustainability is meaningful in the research site, it is important to identify participants' definitions. Sustainability is a broad and encompassing term, and engineering has identified it as a topic to be incorporated into the socialization of new engineers.

Teaching Sustainability Concepts in Engineering

Every academic discipline would benefit by incorporating ideas of sustainability into its curriculum, to better develop students' conceptualization of sustainability and the impacts that current ways of life have on the world and systems around us. Mechanical engineering has particularly important reasons for adopting ideas of sustainability into the design process: the material consequences of creating new technology. If alterations are to occur in the design of structures, vehicles, engines, machines, and manufacturing processes, they must take place with the knowledge and support of mechanical engineers. Engineering as a discipline is a focal point for integrating sustainability into the curriculum because mechanical engineering is linked to industry and engineers are viewed as problem solvers (Ashford, 2004). Societal change can occur if new engineers are socialized to design in different ways (Hanning, Abelsson, Lundqvist, & Svanström, 2012).

The current mechanical engineering curriculum privileges Newtonian empirical thinking and is rooted in physical science. Historically, engineering education has focused on a narrow solution set based on scientific and mathematical principles, not attending to other factors (Bryce, 2004). The engineering curriculum is packed with math, design, physics, and science classes to help students build skills in problem solving and design (Weick & Sutcliffe, 2007). Engineering students sometimes feel that working on soft skills such as communication, writing, and sustainability is not directly important to the tasks of their future and is a waste of time (Anderson et al., 2008). Finding space to add more “nonengineering” interdisciplinary study of the complicated systems that help someone understand sustainable concepts is a difficulty that engineering programs face. However, sustainability needs to become a foundation of how an engineer thinks about the design process (Paten, Palousis, Hargroves, & Smith, 2005).

Fenner et al. (2005) and Peet et al. (2004) claim that designing in a sustainable way needs to become a core foundation of mechanical engineering, a concept that is taught from day one. Sustainable design should not be an elective, specialized section or an afterthought; it needs to be central to the idea of design. Some engineering students believe that they should design products and let the market decide what is successful; however, there must be long-term thinking embedded into the engineering program. This takes interdisciplinary learning and thinking about problems in a larger scale, a more systems-oriented way of thinking (Mulder, Segalàs, & Ferrer-Balas, 2012).

Many scholars feel a shift in thinking is needed, one that broadens the view of the engineer's role from focusing only on the technological to considering society as a whole system (Segalàs, Mulder, & Ferrer-Balas, 2012). This systems thinking adds additional curriculum that expands the scope of engineering to include a spectrum of concerns and disciplines, including whole systems thinking, resource management, law, philosophy, globalization, ethics, culture, clean technologies and process, life cycle analysis, manufacturing waste reduction, efficacy, and the eventual disposal of the product. It also requires the engineer to focus on ecosystems, community development, and relationships. It changes the focus of engineering from simply designing the product, to considering how the product will impact the world (Boyle, 2004). The goal of a mechanical engineering education is to prepare the individual for a career in their chosen field, and this includes the development of knowledge and skills that s/he will need to be competent when hired. By incorporating sustainability into engineering education, new engineers should be better prepared to meet evolving sustainability challenges

A need has been established to change engineering education. Some scholars claim that engineering programs are failing to make sweeping changes not because they do not want to, but because there are significant barriers to change. Some barriers include:

Maturity of the students;

Knowledge of sustainability and the environment among lecturers;

Lack of acceptance of sustainability engineering;

Discomfort with interdisciplinary teaching;

Lack of textbooks;

Not knowing where to acquire relevant information;

Difficulty combining environmental and sustainable design information with core curriculum;

No reward for the extra work and innovation;

A perceived threat to ideas of territory;

Worry that environmental understanding is not appropriate for their discipline;

Lack of access to examples;

Lack of support;

A feeling that change is daunting;

Lack of time to create new lessons. (Boyle, 2004; Thomas, 2004)

These barriers are legitimate and difficult to overcome, but listing the reasons why programs are not changing curricula does not sufficiently address the systemic contradictions that mechanical engineering programs face. Instead a mere identification of barriers implicitly assumes a linear model of change that is inadequate.

Many research projects have given an overview of programs and processes they have used to facilitate change. These articles describe a sustainability program that was implemented into an existing engineering program (Abdul-Wahab, Abdulraheem, & Hutchinson, 2003; Boyle, 2004; Bryce, 2004; Davidson et al., 2010; Desha, Hargroves, & Smith, 2009; Dincer & Rosen, 1999, 1999; Fenner et al., 2005; Ferrer-Balas, 2004; Fox, Hundley, Cowan, Tabas, & Goodman, 2009; Hadjamberdiev, 2004; Hanning et al., 2012; Lundholm, 2004; Mulder et al., 2012; Nagel, Pappas, & Pierrakos, 2011; Pappas & Pierrakos, 2010; Paten et al., 2005; Peet et al., 2004; Prins et al., 2008; Rowley, Yelamarthi, & Bazzoli, 2008; Svanström et al., 2012). These descriptions of change are informative as individual descriptive cases. They are, for the most part, a-theoretical, and situation-specific. Scholars have noted, however, that there needs to be a switch from descriptive research to research that draws upon organizational theory (Fien, 2002; Thomas, 2004)**.** By situating the study in structuration theory and identifying relevant contradictions, this study examines the complexities of socialization and change. Having established the need for both an examination of sustainability education in engineering and research that goes beyond mere description of such curricular changes, the remainder of this chapter will be devoted to explaining the conceptual tools used throughout this study.

Socialization

Socialization focuses on the process through which a newcomer becomes part of an organization. Through socialization, individuals learn the values and expectations of being members of an organization. The education process at a university is part of the anticipatory socialization process as students become members of a chosen vocation. They learn the norms, culture, skills, and knowledge that are expected of them as they become professionals (Mendoza, 2007). Pascale (1985) defines socialization as "the process of being made a member of the group, learning the ropes, and being taught how one must communicate and interact to get things done" (p. 27). Neophytes learn about the general profession prior to being employed by a particular organization. Jablin (1984) introduces the concept of assimilation that expands the idea of socialization to include the actors and acknowledge their agency as they become a member of an organization. Organizations are created through a process of crafting an understanding of norms and expectations and reproducing them. It is not a fixed process; instead it is dynamic (Heiss & Carmack, 2011).

The process of socialization or assimilation is not one through which the organization indoctrinates the actor with the actor having no agency of his or her own. In fact, the individual who joins the organization comes with a set of experiences and expectations that impact how s/he fits into the organization and can possibly change the organization (Stephens & Dailey, 2012). Newcomers individualize their roles, often leading to innovation as they adapt their roles through the role-taking process. Scott and Myers (2010) argue that there is an overemphasis on structure in most socialization literature and more power needs to be given to the agent. Socialization does not have the same effect on all participants, so the process will be as unique as each participant engaging in it (Scott & Myers, 2010). This is an important concept because members of the mechanical engineering department may be active members in embracing ideas of sustainability and may be involved in the process of adopting those ideas in ways that can lead to changes in addition to the actions the department takes to socialize them.

This study focuses on this socialization and assimilation into the profession, during which neophytes learn, in general, how to do their professional work and what is expected of them in order to be successful. During this process, learners seek clues from colleagues, superiors, subordinates, clients, and other associates. As they learn, they understand how the organization works and how they fit into it, attaining knowledge about organizational (and professional) history, language, politics, people, goals, values, and performance proficiency (Chao et al., 1994; Cooper-Thomas & Anderson, 2002; Jablin & Kramer, 1998; Van Maanen, 1976). The aim of socialization is for an individual to understand the organization, how it works and how they fit into it. The process is shaped by the resources the organization invests in it; for example some orientations are long and a great deal of money and time are spent on welcoming the new member, while others are short and less formal. Indeed, Gomez (2009) points out that if time is considered a limited resource then socialization will happen outside of structured training. Individuals will be left to their own devices or informal, unstructured activities to understand how the organization functions. In these situations, new employees can be socialized by watching established employees because those established employees are re-creating the structures of the organization (Poole, Seibold, & McPhee, 1985). Some organizations offer an organizational member already familiar with the organization to help facilitate the newcomer's entry (Heimann & Pittenger, 1996). As students at the university learn the intellectual skills needed to be mechanical engineers, they are also learning about what their roles will be once they are employed; additionally, they are bringing beliefs, ideas, and ideals to the department. The process of an undergraduate education serves to socialize students into the field of engineering.

It is within the process of socialization that the importance of sustainability in the design process will become meaningful to new engineers. As they are learning the knowledge and skills needed to engineer, they will also learn the values and ethics expected of engineers. Dynamics in this site will determine if sustainability will be of importance or not.

Socialization has been theorized as a series of stages during which varying strategies, tactics, and experiences result in varying levels of adaptation, satisfaction, identification, and innovation (Cheney, 1983; Jablin & Kramer, 1998; Jablin, 1982; Pascale, 1985; Jablin & Putnum, 2001; Wilson, 1984). One weakness of this model is that it assumes new employees are entering into a stable environment and does not account for organizations experiencing change. It also overlooks how established members socialize new individuals while the expectations of these established members are changing as well. A more nuanced view of socialization that explores an organization in flux would be a beneficial addition to socialization scholarship. This view would not assume that socialization is occurring in a stable environment. It also would not assume that established organizational members, in this case mechanical engineering professors, know about sustainable design. By focusing on identifying the tactics and outcomes of socialization, theorists have overlooked the complexities of socialization, including resocialization with respect to change.

The process of the engineering community embracing the ideas of sustainable design is an example of an organizational change that requires existing members to be socialized to new ideas. In traditional organizational socialization models the individual joins an organization, is socialized, and builds identity. Information provided during socialization can be a resource used as individuals are acting within an organization (Hart, 2012). Throughout the course of an individual's tenure with an organization s/he will incrementally be resocialized as the organization evolves. For example, a new governmental environmental regulation can modify the standards of design, which subsequently will alter the environment of the organization. Consequently, individuals will have to be resocialized to the new environment. In the case of the mechanical engineer, the professors who are socializing the students are also being resocialized into new ways of thinking about sustainable design. Scott and Myers (2010) explore socialization and assimilation with the Giddens lens of duality of structure. They offer a metaphor of the river first presented by Cheney et al. in *Organizational Communication in an Age of Globalization* (2004) as an example of how the socialization process works:

> Just as water flows continuously through a river, individual attachment is always changing and requires ongoing reaccomplishment. As this continuous movement proceeds fairly predictably within boundaries of a river's banks, reification of one's role and organizational attachment constrains behavioral options considerably. Job holders may come and go, but the role boundaries associated with a particular position are often resistant to change. (p. 20)

This is a demonstration that the organization or the riverbed creates a structure; however, the agent might navigate through the structure in multiple ways, changing course continuously.

Because the nature of mechanical engineering culture is changing from one that designs carbon-producing cars and machinery to one that is more aware of the environmental impact of design, the way engineers are instructed about this new approach to design is important to cultural change. Socialization is the site where this happens; it is a localized site where contradictions manifest. In order to better understand the integration of sustainability into mechanical engineering, this study focuses on the manifestation and negotiation of contradictions in the socialization process.

Resocialization is complicated for incumbents. It involves embracing a new way of functioning in a shifting setting. Organizational change, although inevitable, can be anxiety-producing. Organizational communication theorists have explored the subject of change extensively (Jian, 2007; Lewis, 2006, 2007; Lewis & Seibold, 1993), and it is still a process that is uncertain. At the crux of investigating these contradictions is socializing mechanical engineers. This requires inquiry into how organizational change occurs and how it can be managed.

Organizational Change

The study of change in organizations often falls under the category of applied communication research. Subjects concerning organizational change span from examining the best communication strategies to enact change and stages of change implementation to the change agents' role, how to involve employees, and resistance to change. This study examined contradictions as indicators of where change is likely or possible. Before exploring why contradictions are the foundation of this study, an overview of literature about organizational change and what makes it successful or not is introduced to provide an overview of how change is often framed.

Communication During the Change Process

Theorists have two dominant ways of conceptualizing change: episodic and evolutionary. Episodic change assumes a specific change goal that is then implemented through distinct beginning, middle, and end phases in the "period of change." This theory of change is top-down and assumes that change occurs as interventions are enacted upon the organization and then are eventually accepted by all (Dunphy, 2007; Kotter, 2007; Lewin, 1951). Lewin's (1951) classic change model introduces a three-stage change program that includes unfreezing, changing, and freezing. Unfreezing occurs when the motivation for change has been created, and people are convinced that the existing manner in which things are being done should be changed. The change then occurs, after which freezing facilitates the maintenance of the new ways of doing things.

The theory of evolutionary change complicates the idea of episodic change and brings us closer to structuration. This concept speaks into how change is a more complex process that occurs outside of discrete stages. This theory is modeled on Darwin's theory of evolution, in which an organization keeps practices that help it thrive and abandons ineffective practices, so that the organization is always changing, and sloughing practices that are ineffectual (Monge & Poole, 2008; Weick & Quinn, 1999). Much of the evolutionary model focuses on how members of organizations create change through dialogue. Conversations and reflexive dialogue are where change occurs in organizations. They are a way for organizational members to share information and absorb new concepts (Jacobs & Heracleous, 2005). Thomas, Sargent, and Hardy (2011) discuss the process of organizational becoming in which "'Organization' is an emergent property of change—a temporary pattern constituted by and shaped from micro-interactions among actors, situated in their everyday work. Change is endemic, natural, and ongoing" (p. 22). Because organizations exist through language, they change and restructure through language use.

Although it has been noted that both episodic and evolutionary change are necessary and present in organizations, such models are problematic because they are oversimplified. A quote from one of the interviews that Harris and Crane (2002) conducted demonstrates the failure of a top-down environmental change initiative. Without the combination of buy-in and leadership from every level of the organization, and education and discussion throughout the process, organizational members end up feeling confused about the change:

> Change and especially green change isn't a simple issue. I mean, what does green change actually mean? I've been persuaded that green issues are important, but [skeptically] do my managers genuinely believe or is it lip service to keep the old boy happy? Probably. Does that make us green or not? Yeah, we've got some "green" strategic objectives- I wrote them myself-Is that green change? (Consumer products firm, company director). (Harris & Crane, 2002, p. 221)

If change is forced upon an organization without giving members the chance to synthesize the information, resist it, and research it, the change is more likely to be opposed and perhaps will not occur.

Somewhere in the middle ground between the episodic and evolutionary models, Lewis (2007) and Lewis and Seibold (1993) offer a model that represents an actor facilitating change and then the organization either adopting or not adopting it due to structures and organizational attributes. This model focuses on the importance of the communication strategies used by those who implement change. Lewis (2007) notes that change impacts people throughout every level of an organization, and therefore multiple stakeholders need a voice in the change process. The opportunity for anyone who wants to be involved in the change process is imperative. "This model posits that an implementer's recognition of stakeholders, identification of their relative stakes, and strategic adjustment to identified stakes and stakeholders are key predictors in accounting for outcomes of planned change implementation communication" (Lewis, 2007, p. 179). This model combines episodic and evolutionary change. Understanding the importance of stakeholders' participation implicitly acknowledges that contradiction exists within actors' voices and behaviors.

Although there are many factors that have been associated with successful change, ranging from the timing of change (Wezel & Saka-Helmhout, 2005) to the reasons for its implementation (Dunphy, 2007), the most consistent suggestion for successful change implementation has focused on communication. Much research postulates that the way an individual feels about the change impacts how successfully change is implemented into the organization (Lewis, 2006; Rooney et al., 2010). The next section of this chapter will discuss communication in the change process as organizational members communicate about change.

When change is viewed solely as either successful or not, a focus of the research becomes why people do or do not adapt to the change, including barriers that mitigate against successful change. Often individuals express resistance or unhappiness about the change. "Fear of change, fear of unpleasant consequences, lack of trust, uncertainty, poor training, surprise, and personality conflicts are all listed as reasons that employees resist change" (Lewis, 2006, p. 27). People enjoy the sense of community they find at work, and change threatens an employee's sense of continuity in the work environment (Rooney et al., 2010). Interestingly, Stanley, Meyer, and Topolnytsky (2005) find that individuals are cynical about change in an organization if they did not trust management to begin with. Change is difficult, and often individuals cannot appreciate the process because of their overwhelming sense of insecurity that what they like about being part of an organization is going to change.

Many suggestions for successful change efforts are rooted in clear communication (Seibold, Lemus, Ballard, & Myers, 2009). Recommendations about good communication during change range from being honest and transparent, creating a participatory process, creating goals, reducing uncertainty and anxiety, and making sure key stakeholders are involved (Barge, Lee, Maddux, Nabring, & Townsend, 2008; Lewis, 2007; Lewis, Schmisseur, Stephens, & Weir, 2006). Vasi (2006) recommends focusing on the big-picture benefits of the change and making open communication the foundation. These ideas of communication-based change often emphasize the importance of the actor and ignore the system in which the actor is operating.

Other studies shift focus to organizational structure and hierarchy, which are viewed as something that can either support or hinder change efforts. The choice of communication channels used to inform members about a change is important. Where an individual is placed on the hierarchical structure has an impact on how s/he feels about change. Those who are involved with the implementation are more familiar with the expected outcome so it is less threatening to them. However, those who are told about the change through informal or inaccurate channels are less informed and more anxious about the ambiguous goals of the process (Rooney et al., 2010). An example of this predicament was explored in an article by Brinkhurst, Rose, Maurice, and Ackerman (2011) in which they note that many efforts of making sustainability changes on campuses are credited to either grassroots student efforts or mandates from upper administration. They point out the disadvantage of this tendency is that both of these groups are not altogether familiar with the everyday campus happenings and how to navigate the bureaucracies of the institution. An alternative is for campuses to encourage entrepreneurial, middle-level staff and faculty to create projects leading to more sustainable campuses. Conceptualizing a change process as a list of dos and don'ts creates a modern concept of change that gives instructions for the one correct way to progress in an organization.

To offer tools to implement sustainability into an organization, Dunphy (2007) presents a series of steps to guide the process. These tools offer a top-down strategy to become more sustainable, specifically targeted to corporations. Based on the premise that corporate organizations are the foundation upon which the modern economic system is built, it stands to reason that if organizations do not adopt more sustainable practices, the likelihood of large systematic changes is slim. In addition to offering a change model, Dunphy (2007) offers compelling arguments to organizations about the advantages of adopting sustainable practices that expand beyond environmental objectives. These reasons range from creating new global networks made up of biologists, scientists, corporations, NPOs, and NGOs, to leading the industry by going beyond environmental compliance, to the strategic advantages sustainability offers a company. In the tradition of episodic change models, this change process is presented in a series of steps.

When change is viewed as a process of making people do what change agents want, the models can be overly simplistic. Although sometimes top-down approaches are appropriate, a focus beyond a top-down approach is another interesting way to investigate change. Additionally, a deeper investigation into the specific points of change would be a helpful and much-needed addition to change literature. An aspect of change that is often overlooked or undervalued is the importance of understanding the details within the setting. Models indicate that change happens as people struggle in settings (Baker, 2009;

R. Thomas et al., 2011). Contradiction gives us a way to illuminate the sites of struggle. The specific identification of contradictions and how people manage them will illuminate the points in an organization that are open to transformation.

Contradictions

This overview of change literature illuminates that change is difficult and there is no panacea model or formula that will facilitate change. Top-down change, change models, evolutionary, and linear ideas of change all have aspects that are problematic. However, sometimes change is necessary. In situations such as climate change, a different approach will be necessary, either to try to mitigate the climate change or to adjust to the effects of it. With that in mind, the idea of contradictions as presented in cultural historical activity theory (CHAT) can be turned to for a different understanding of change that addresses the issues regarding previous conceptions of change. When the goal is collective transformation, identifying contradictions can provide a path. Contradictions are imbedded within societies, institutions, and organizations and are often citied as a place to examine organizational change (Engeström & Sannino, 2011). Giddens (1979) defines them as “disjunction of structural principles of system organization” (p. 131). New ways of structuring and performing activities are revealed through contradictions (Foot, 2001).

> Although actors can become reflexive at any time, the likelihood of a shift in collective consciousness that can transform actors from passive participants in the reproduction of existing social patterns into mobilized change agents increases when actors continually and collectively experience tensions arising from contradictions in a given sociohistorical context. (Seo & Creed, 2002, p. 230)

Identifying contradictions is a way to locate fissures in an organization in which change is possible. These fissures are caused when structural principles oppose each other – they are dependent on each other, and yet they negate each other. Contradictions are not set up as a problem/solution situation; instead they must be identified, and then structural changes can occur (Giddens, 1984).

> Activity theory uses the term contradiction to indicate a misfit within elements, between them, between different activities, or between different developmental phases of a single activity. Contradictions manifest themselves as problems, ruptures, breakdowns, and clashes. (Kuutti, 1996, p. 34)

Contradictions manifest themselves in organizations as opportunities for a different way of organizing to occur. Foot (2011) calls them "illuminative hinges" and members can use them to envision a future, identify opportunities for growth, and as an indication that an organization is alive and altering and developing. Contradictions should not be viewed as system failures or criticism. Instead they are starting points for revisioning an organization. Trying to fix contradictions is not the goal of identifying them, but rather the value lies in opening new ways to examine an organization. Contradictions can drive institutional change. However a contradiction does not guarantee change (Seo & Creed, 2002). Engeström and Sannino (2011) observe that identifying contradictions allows an opportunity for thirdness -- not a compromise, but a new way of doing things. By identifying them, new opportunities for the organization exist, but they do not have to be taken. Through my thinking about the contradictory nature of these issues and how confronting them could offer exciting new ways to look at issues, I coined the term obstacle-tunities.

By examining the many levels of contradictions, a framework of how organizations are created and change through communication can be created and used for gaining deeper understanding (Engeström, 1987). These contradictions are locations within organizations that are ripe for transition. Foot (2010a) and (2011) posit that identifying all four levels of contradictions is necessary to explore how and why systems are evolving. This is why Engeström (1987) presented four levels of contradictions: primary, secondary, tertiary, and quaternary. Primary contradictions are inherent tensions that exist between the many individual aspects that make up a system. Primary contradictions exist because of the nature of systems. Secondary contradictions involve two elements that are in tension; these are exposed when a new element is added to an existing system. Secondary contradictions cannot be resolved without the systems transforming. These contradictions exist when two systems are contrary to each other. Tertiary contradictions occur when a new, more advanced entity is introduced into an activity. This new addition creates the contradiction, and the only way it will go away is through a change in practice or systems. Finally, quaternary contradictions are when the contradictions exist between the central activity of one system and the actions of another or when one system hinders the performance of another (Canary, 2010a; Canary, 2010b; Engeström, 1987; Foot, 2001) .

Contradictions are necessary parts of systems and developments or change are the result of contradictions (Foot, 2001). By identifying contradictions as precisely as possible using primary, secondary, tertiary, and quaternary levels and by identifying where they happen, perhaps we could pinpoint where an intervention could happen within an organization that would also impact the system and the structure.

If, as a society, we are entrusting engineers to help bring about a more sustainable way of living, then concepts of evolution, socialization, and change will help to understand this challenge in a more nuanced way. Additionally, it will take the examination of the micro- actions of members, along with the macro-systems within which the organization operates, to learn how change actually happens. Using the lens of structuration and interrogating the contradictions involved in the socialization process during this time of change can shed a new theoretical light on this topic in hopes to mitigate climate change.

Structuration

From the evolutionary viewpoint of change, it is through the conversations and interactions of organizational members that change occurs. Although Anthony Giddens' theory of structuration (1984) is not discussed as a change theory specifically, the concept of individual actions changing the entire organization is elegantly expressed in structuration theory. The foundational premise of the theory is that actors are shaped by the structure of organizations and that organizations are shaped by the actions of individuals. Through this theory, both the micro-(an individual actor's actions) and the macro-(structures that make up society) aspects of communication can be studied simultaneously. Poole and McPhee (2005) identified three foundational concepts that need to be identified to understand structuration theory: structure, or "the rules and resources drawn on by actors in taking part in system practices"; rules, which are "any principle or routine that guides people's actions"; and resources, or "anything people are able to use in action, whether material (money, tools) or nonmaterial (knowledge, skill)." Since both rules and resources make up structures, differentiating between the two is important. Structuration theory assumes that when actors utilize those rules and resources they keep the system going and reproduce the structures. It is the examination of change using these rules and resources that makes structuration uniquely qualified to examine this case. The rules (such as the number and kind of credits necessary to graduate, requirements for classes, what is expected in a design process, tenure) and resources (good grades, funding, knowledge) available to mechanical engineers as they do or do not incorporate sustainable ideas into their design will illuminate the structural contradictions that make this change process difficult. The reproduction of systems does not happen without change, and as actors transform behaviors the system is modified (Poole et al., 1985). Contradictions reveal the need for change, which occurs as actors then wrestle with new or different combinations of rules and resources. According to structuration theory, social structures are constantly changing, especially in how rules and resources are utilized.

Structuration theory proposes that the everyday actions and practices, or micro-practices, that individuals enact are connected to the larger scope of society. Society is made up of systems; systems are comprised of structures, rules, and resources that actors draw upon while participating in system practices to create structures.

Systems and Structures

Systems are the way that structures organize; for example, the systems of how people deal with solid waste are made up of structures such as trash collections, landfills, and recycling. The systems are not static and can change. For instance, residential recycling pick-up was not always offered, but the structures changed and so did the systems. Structures are created through communicative acts.

Structures also are created by the actions of people. These actors' behaviors have routinized aspects that are influenced by existing social structures, but the actor reifies those structures by enacting them. Furthermore, structures, or the rules and resources that are available to them, influence actors' behaviors.

> Structures are virtual properties of social systems, the broad arrangements among members of society and focal institutions. Produced and reproduced through human symbolic activity, structures guide social interaction by enabling and constraining behavior. Structures are best thought of as formal and informal rules, symbolic resources, and sets of transformational relations found in ongoing social interactions and practices. (Giddens, 1984 as cited in Scott & Myers, 2010, p. 80)

Structure and action are constantly influencing each other. In other words, structures are created and recreated because people often do the same thing again and again. They do this because of the ontological security that routine offers. Human behavior is influenced by the structures, social norms, or rules that exist in a society; in turn, structures are influenced by human behavior.

Because structure and action are always influencing each other, structures are not constant. In fact, according to structuration theory, social structures are constantly changing. Societies and social interactions are real; however, they are produced by actors repeating or not repeating behaviors, thus social structures are not of the physical world, and they change through time and space. As new combinations of time and space come into being, new rules and resources come into being as well, in a process of distanciation. Because agents have the ability to act, they are powerful. An agent's ability to act in turn influences a structure or state of affairs. Because individuals have agency, one can break from normative actions, which can spark change in social structure. Generative action is the dynamic between structure and agency (Giddens, 1984).

Systems and structures are produced and reproduced through action. Structures are created through social practices—actions that are inspired through structural history manifesting from memory traces. In other words, memory traces are what we know about things, and structures are created from what we know. The more the structures are reproduced, the sturdier the structures become. In this way, a structure is limiting and enabling at the same time. For example the mechanical engineering program is historically and currently linked to the automobile industry, and so many of the senior design projects are competitions sponsored by car manufacturing companies. The more opportunities given to students through designing projects with a combustible motor, the more emphasis is given to the importance of oil-based design. Additionally, when students are not asked to consider the carbon output of the design, they are not creating memory traces of the environmental impact of what they are creating.

Benefits of Structuration for This Study

Structuration theory offers a lens to examine organizational communication that can focus on both the communicative actions of an agent and the structures in which that agent operates. It is a theory that allows micro- and macro-actions and structures to be acknowledged. Structuration theory is also especially helpful as a lens through which to study organizational communication because it helps to illuminate how organizational structure arises outside of formal structure or hierarchy. The official organizational chart exists, but often those who study change note that many change efforts fail. Structuration offers an explanation of how organizations work that gives value to agents outside of the official organizational chart. Structuration theory provides a way to acknowledge that hierarchy is distinct from an organization’s rules and resources.

Structuration theory is also an important concept when considering organizational changes that will make an organization more focused on sustainability. A significant change in the mechanical engineering department will happen one micro-action at a time. People are discouraged from engaging in environmentally conscious activities such as recycling because they feel that as individuals they cannot make a difference. However, multiple micro-actions result in significant structural change. For example if every person decided to stop using plastic grocery bags, then there would be no need to manufacture them and the waste created by plastic shopping bags would be eliminated. One reason that structuration is an interesting fit for environmental issues is that the availability, use, and allocation of resources is changing. Structures will change because access to resources is changing due to global climate change, population growth, and the diminishing of easily accessible fossil fuels. Evolutionary change processes are such that change occurs constantly, due to micro-actions from each member of an organization.

Interactions and enacted agency occur in the here and now. However, structural properties result from memory traces or learned ideas of how structures work. Historical context is important, then, and it is a potential site for contradiction. In the example of mechanical engineering education, ties to oil-based technologies are strong, as explained above. This historical context is now in conflict with a larger and more contemporary context of global climate change. The larger context of global climate change and its intersection with the traditions of mechanical engineering is an important issue. This contradiction is one that exists for an industry with a history entwined with machining and petroleum industries and is now facing pressure to design sustainably.

Professors, staff, and students, as agents in the mechanical engineering department, can change the way that sustainability concepts are communicated. Adding lectures that frame sustainable design as an opportunity for new engineers will change the way the concept is discussed. Student participation in class and extracurricular activities could open a new way of addressing this issue. Additionally, the structure of the mechanical engineering department can be changed as assignments and traditional activities are modified. For example, currently seniors in mechanical engineering have to participate in a senior design project. It is a project that spans the entire school year and gives the students the opportunity to take a design project from conception to completion. Currently in the design process students do not have to consider where the raw materials for the project are extracted and the environmental consequences of that extraction. Additionally, students do not have to compute what the carbon impact of the design is. And finally, they do not have to think about where and how the product is disposed. Because of this, none of the current rules of design require the students to think about the impact that the design has on the earth. In other words, sustainability is not part of the mechanical engineering structure. The acquisition of natural resources and the disposal of products are unconsidered and constitute a contradiction within this system. Conceivably, an emphasis on these ideas within the socialization process would create an engineering paradigm that considered sustainability.

The last concept of structuration that will be interesting for this project is time and space distanciation. Time and space are an important part of structuration. Currently the mechanical engineering department is located at a crossroads of traditional ways of engineering on a timeline that assumes that a constant supply of natural resources will be available. In this traditional belief, time has no limit, and the traditional practices of design and engineering can go on forever. However, because of the aforementioned issues of increased population, global climate change, and limited resources, the timeline is changing. Climate scientists state that the adoption of new techniques can't happen at a leisurely pace; it must happen now (Pachauri & Reisinger, 2007). Time and space are important to the mechanical engineering department at Mountain State University. At this intersection of the traditional timeline and Mountain State University mechanical engineering program is a new configuration of time and space or distanciation. This new concept of time is a race to change structures before CO_2 levels are too high. This intersection could allow for the possibility of new structures that design in a more sustainable way.

Contradictions

Like CHAT, Giddens (1984) also states that abstract contradictions happen in every system and that these contradictions can't be solved with simple fixes. It is these contradictions that facilitate deep change within systems. This does not necessarily mean a top-down mandate for things to be done differently, but instead the entire organization is suspended in a space of contradictions and shifts in response to those contradictions. Contradictions are viewed as negative when they reflect policy inconsistencies that cause confusion or conflict and make implementation of policies difficult for those who support the policy and those who oppose it (Canary, 2010a) . The issue at hand is a good example of a set of contradictions that will require a deep systemic change: The engineers need to change the structure to take climate change into account, but they are being rewarded for traditional patterns of design. The system is set up for immediate rewards that are in conflict with the pressing future dangers of pollution and global climate change. This is a contradiction between conflicting structured pressures.

Canary (2010 a, 2010b) introduced structurating activity theory as a tool for organizational communication scholarship. This theory is grounded in structuration theory using the constant influence of micro- and macro-systems on each other. Structuration is combined with CHAT, which uses the system of activity as the unit of analysis (primary, secondary, tertiary, and quaternary contradictions) but acknowledges that those systems are connected to other systems. This theory creates a model in which the insights of structuration theory, especially regarding contradictions, can be harnessed, explored, and made more sophisticated and complex.

Organizational change is difficult. Even though world leaders, climate scientists, environmentalists, and individuals see a need for changes to occur that will mitigate the effects of climate change, dramatic action called for by individuals like Giddens in *The Politics of Climate Change* (2009) have not occurred. Sweeping changes seem overwhelming and impossible to implement. Because of that, an identification of contradictions within observable activity systems is needed using SAT to identify primary, secondary, tertiary, and quaternary contradictions. Through the process of identifying sites within the organization that may be conducive to change, we can pinpoint how actors struggle within these contradictions and how communication is managed to address those contradictions. By understanding structure and system, a more nuanced and strategic set of recommendations and interventions can be suggested that may focus on opportunities for organizations to evolve and hopefully feel less overwhelmed than they feel from an unfocused mandate for change.

This literature review has given an overview of the difficulties of incorporating sustainability into engineering education, socialization, organizational change, and structuration. All of this is leading to an exploration of the contradictions within the mechanical engineering department that will help diagnose localized areas where change could happen. Climate change is happening and thus far, sweeping change has proven difficult to implement. A different tactic needs to be used to try to create a new vision for how things are done. Examining contradictions can help to identify where opportunities for new ways of doing things are possible. By identifying where the contradictions happen using SAT and how individuals navigate contradictions within the Department of

Mechanical Engineering at Mountain State University, perhaps this study can help to pinpoint areas for possible new ways of doing things, creating obstacle-tunities. Although SAT has theoretically outlined how identifying contradictions can be a facilitator of organizational change, it has yet to be applied to multiple case studies. This project offers an opportunity to apply this theory in a case study.

Research Questions

Research Question 1: How do the people in this setting make sense of sustainability?

By painting a picture of the attitudes and ideas concerning sustainability, RQ1 sets the reader up for the identification of contradictions in later research questions. Understanding the classes that are offered and the way environmentalism and sustainability are discussed allows the reader to get an idea of the department and its culture.

Research Question 2: What are the contradictions (macro and micro) and how do they manifest communicatively within the socialization process of novice mechanical engineers? How are contradictions managed and negotiated within this site?

- How do actors use structures (rules and resources) as they negotiate the contradictions?

CHAPTER 3

METHODS

Qualitative Investigation of the Mechanical Engineering Program

This study is a multimethod interpretive qualitative project that will examine the culture of sustainability at Mountain State University's Department of Mechanical Engineering. The study includes surveys, interviews with students and professors, a close reading of students' essays about sustainable design, and participant observation with the end goal of understanding what contradictions exist and how they are manifested surrounding sustainable design.

To gain access to this population, I received support for the project from the chair of the mechanical engineering department. To help me meet participants he wrote an email to mechanical engineering professors asking them to participate in the project. He specified that involvement in the project would include being interviewed by me, putting me in touch with students I should speak to, and allowing me to attend class and to hand out surveys. Students were encouraged to participate by professors' offering extra credit, but they were not forced to participate in any way. This served the project well, and I was delighted with the willingness of professors and students to participate.

Design and Study Procedures

The survey and interview questions were not explicit in asking organizational members how they are socialized about sustainability and where contradictions exist. Instead I drafted a series of questions that helped me establish what information about sustainability they were learning, where they were learning it, their opinions about global climate change, and how they saw concepts of sustainability fitting into their careers as mechanical engineers. Together with the observations and the analysis of documents and a variety of web sites, the details of the answers they gave provided a holistic and comprehensive view of this setting. By asking open-ended questions about the socialization experience and sustainability, multiple possibilities for answers were exposed and a larger view of what is taking place could be achieved (see Appendices A and B for the interview guide). As I analyzed and presented the information about this organization pseudonyms were used for individuals and the university.

Surveys

Surveys provide an opportunity to get a large sampling of ideas, statements, and opinions. Additionally, because they are anonymous and can be taken in the respondent's own time, they may allow for more honest answers. These surveys asked questions that would help to establish students' attitudes and knowledge about environmental issues and sustainable design. The survey included both Likert and open-ended questions so that students could express themselves about sustainability and the rules and resources available to learn about sustainability. Surveys (Appendix A) were conducted in mechanical engineering design classes (ME EN 1010, ME EN 2010, ME EN 3010, and ME EN 4000) and given online at the end of the semester (fall 2011) using a website through which the class members communicated with each other throughout the semester. Completing the survey offered students an opportunity to express their knowledge of sustainable design, where they were learning about these ideas, and whether they thought sustainable design would be relevant to their careers.

The questions on the survey attempted to establish the student's position with regard to knowledge, values, and how they were being socialized to ideas of sustainability. A total of 259 surveys were completed, with 126 being completed by freshmen, 75 by sophomores, and 58 by seniors.

Interviews

Interviews are an intimate and privileged opportunity for a researcher to learn how the interviewee experiences and sees the world. The interview is important because the researcher and the interviewee come together on a sense making mission. In the process of interviewing, the interviewee reports their perception of people, places, things, and events. It is important for the interviewer to remember that people have their own points of view and that perhaps memories could be inaccurate. Because of this, more important than reporting what happened is revealing the social actors' perspectives of events and people and how they articulate them (Lindlof & Taylor, 2011). Interviews allow the researcher to experience the language of the participant, to gather information that can't be observed, to inquire about the past, and to compare information from other sources.

For this project I interviewed 38 individuals including 1 staff member, 21 students currently enrolled in the program, 13 professors, and 3 professional mechanical engineers currently working in industry. The interview participants were contacted by email or phone and I requested a 30-45-minute interview. These interviews were recorded with the permission of the interviewee. I also took notes throughout the interview. Unfortunately, the tape recorder malfunctioned so that 8 student interviews and 1 professor interview were unavailable. I relied upon the notes I took during and after these interviews. Interviews ranged from 13 to 90 minutes. I hired a professional transcriptionist. In the interviews (Appendix B) the participants were asked to identify the rules and resources that encourage or discourage sustainable design in their studies and practice.

To recruit individuals to participate in interviews I used a few methods. For students I asked professors and TAs whom I knew if I could make an announcement in class and pass around a sign up sheet. After students signed up I emailed them to set up a time to meet. I also used snowball sampling with participants I interviewed and had them suggest other students with whom it would be good to talk. To recruit professors I started with professors with whom I had worked in the CLEAR program. After interviewing them, I emailed each professor in the mechanical engineering department and asked if they would participate in an interview. Through email we scheduled meetings. The 3 professional engineers were recruited through snowball sampling.

Interviews were designed to enable individuals to talk about sustainability in their own words and to describe their experiences. Questions such as, “What is your favorite aspect of mechanical engineering?” helped me to determine what is important to the interviewees. Interviews also allowed me to find out about what they knew about sustainable design and how they learned it. Interviews provided a window into the socialization processes they are experiencing and the knowledge they have acquired. Asking, “Have your mechanical engineering classes connected the ideas of sustainable design, global climate change, and engineering?” offered an opportunity for the interviewees to think about places where these ideas might have come together and suggest where these connections could have been further emphasized. Last, by allowing them to say anything else they wanted at the end of the interview, I afforded them the opportunity to reveal knowledge I could not have anticipated. The questions asked allowed students to talk about how they are socialized to ideas of sustainability.

Material Culture

Material culture can be viewed as artifacts made by humans. Studying material culture allows researchers to identify how and why people adopt objects, use them, tell stories about them, and how they fit into people's lives. A great deal of knowledge about the department's culture can be found through official documents, websites, textbooks, syllabi, the research projects and design activities in which they participate, assignment descriptions, and completed assignments (Lindlof & Taylor, 2011). These materials were examined to identify the ways that sustainability is being communicated. I examined classes offered, whether there were rewards for sustainable design, and what the department required to understand sustainable design.

Documents are advantageous because they offer a great deal of information, are readily available, are in frequent use, and are constant objects, not changing unless deliberately altered. The examination of official documents such as graduation requirements and the department handbook gave me access to the written rules that the department members have outlined. The website provided access to the mission statement and the descriptions of what students could anticipate learning.

As mechanical engineering professors tried to incorporate ideas of sustainability into the coursework, some were assigning papers and projects that required students to research and explore concepts of sustainability. Close readings of students' written work helped to reveal intellectual contradictions they were experiencing in their work. By reading the words they presented in assignments for class, a clear understanding of how they define concepts and important features of sustainable design was illuminated. Lindlof and Taylor (2011) state, "Texts, objects, and spaces do have a lot to 'say' when we read them alongside the living voices of informants and other social actors" (p. 217). For this reason, material culture and documents were used in this study to investigate how ideas of sustainability are communicated and what contradictions exist therein. Investigating the department's written documents and the students' assignments indicated how they conceive of these concepts. Pairing these material objects with interviews, surveys, and observation offered a robust insight into the manifestations of contradictions surrounding sustainability.

Participant Observation

Because the mechanical engineering department welcomed this project, I was able to utilize many opportunities for participant observation. Lindlof and Taylor (2011) describe participant observation as the opportunity to enter the chosen environment to study, experience, and record events as they take place around you. When doing participant observations it is important to use all five senses to smell, feel, taste, see, and hear what is going on. Any time a researcher is in the field, s/he needs to note the details of what s/he observes, because although they may seem inconsequential, they could fit together for a larger picture in the long run (Angrosino, 2005). By taking detailed field notes, the researcher is later able to recall the environment and make sense of what was happening, discovering contradictions that can only be revealed over the course of time.

Through participant observation, the researcher is able to gain a deeper understanding of the context of the study: the actors, scene, interactions, and events.

I engaged in observations in what Adler and Adler (1987) describe as an active member researcher. I did not take part in participant observation in the traditional manner of data collection, thinking of myself as an objective reporter. Instead I worked in a newer tradition, presuming that the ethnographic process entails entering into a dialogue with the members of the group being studied. I taught classes, interacted with students in labs, and created lesson plans with faculty. Emerson, Fretz, and Shaw (1995) talk about getting close to the members of the community being researched as they participate in their everyday lives. By doing this as a researcher the things that are important to community members and how they talk about those things come to light.

The first and most important step in participant observation is to show up; the researcher must be present, spending time with the community s/he is studying. I accomplished this step by being a part of the mechanical engineering department for 3 years. In addition I observed classes, special lectures, student-run events (such as senior design day), small group meetings between students and/or faculty, and casual interactions in the department. By being there and being active, I was a participant in the community while making observations. In total I observed 186 hours within the department. It should be noted that as I was participating in this community my presence within the site had an impact. I made friends, taught lessons, and created relationships with the participants. My presence sensitized participants about sustainability and impacted interactions. Although I built rapport in this community I understand that my position was, nevertheless, marginal (Angrosino, 2005).

Observations helped identify the contradictions regarding how sustainability concepts are communicated verbally and nonverbally. An example of this was when, in a class that I was working with, the professor mentioned the concept of sustainability. The entire class groaned and the professor responded with, "I know, I know, not everyone's favorite subject." Being present for communicative events such as this provided insight into how the department communicates about sustainable design. By being present, aware, and willing to document what is observed, the researcher can spotlight everyday occurrences and communications for interrogation about what these communicative moments mean. Being present in the situation is a large part of successful participant observation, but the other important part is taking field notes to record observations.

How the researcher records observations and takes notes is of the utmost importance. The methods used for documenting observations, interviews, interactions, and materials directly impacts the findings of the study. Because of this, a great deal of thought, care, and time were put into the recording process (Emerson et al., 1995; Lindlof & Taylor, 2011). For this reason a few ways of recording information were used. The first way was electronic recordings of interviews and classes that I had permission to record, the second was through my field notes, the third was through turning field notes into more detailed notes at home, and the last was a personal journal of my thoughts and experiences as a researcher.

Keeping the end result of the project in mind, all notes and records were part of the process of answering the research questions. Because of this, it was important to have as much documentation as possible. It was important to take notes on everything, because even though it may not seem important at the time, the notes, once viewed in their entirety, could reveal meaning. Through this process I tried to take detailed notes to capture what was happening, logging not only how I observed it, but how the group I studied was making meaning of it.

Data Analysis and Interpretation

The first step in analyzing the data was to read all of it. At this point, all of the interviews had been transcribed, notes from observations and the material objects were typed, and the results of the surveys were printed in one place so that all of the data were in one place in written form. For transcription I used a professional transcriber to convert my audio files to written word. The field notes and journal notes, I typed and organized myself.

To analyze the data for this project, I used a method inspired by grounded theory. Additionally, I used the computer program NVivo to help with the analysis process. Lindlof and Taylor (2011) describe the use of grounded theory as a popular method for analyzing qualitative data. Grounded theory gives the researcher the opportunity to approach the data without preconceived notions of what will be found. Using grounded theory helped to take a large data set and then narrow and identify the important information that answered the question of how contradictions are manifested and negotiated. It let the data reveal findings without a preconceived hypothesis through coding and categorizing (Glaser, 1978; Strauss, 1987). Although I came to this study with preconceived notions of contradictions, grounded theory helped to facilitate the discovery of interviewees' experiencing and sense-making that I could not anticipate or hypothesize before analyzing the data. The process of grounded theory is first to code the data in a wide variety of categories. I did this by downloading all of the data into NVivo and reading it several times.

The next step was to create memos that identified themes of the research and important actors, implications, and interesting questions. Again, to accomplish this, I used the computer program NVivo, which allows the researcher to identify nodes and combine data under themes identified. I ended up with 36 nodes that became the themes identified in this study.

The last step to this type of research is integration and dimensionalization, in which a set of codes are created to make new categories. Grounded theory offers the researcher a clear way to code, organize, and explain the data. This also helps to build relationships between data and theory through process (Charmaz, 2005). Coding was the next step, and the goal here was to create categories in which data can be separated into concepts, constructs, themes, or other groupings. These could come from existing theories selected by the investigator, from demographic information, or from an idea or a theme that appears repeatedly in the data (Lindlof & Taylor, 2011). In this step I thought about the way that information fits together to determine what categories make sense.

First in the coding process is open coding. To open code I read the research data line by line to identify ideas, themes, concepts, and issues. I used these to begin to create categories. The next step is focused coding, in which a more detailed analysis occurs (Emerson et al., 1995). The constant comparative process is a useful activity for refining the concepts and themes in the data. Integration and axial coding were used to connect categories. This brought together separate categories in broader themes, and dimensionalization helped to identify the spectrum of information that was represented in the categories and the many dimensions within each category. While completing this process I wrote memos to myself that focused on phenomena that were difficult to identify or ambiguous findings I observed through this process. Throughout this process I kept in mind the modalities of action or meaning, power, and norms (Giddens, 1984). Once data had been coded they were interpreted.

In the process of interpretation it is important to not only look for themes, but to look for deeper dimensions that are revealed. Lindlof and Taylor (2011) state that interpretation is the process of "translating an object of analysis from one frame of meaning to another" (p. 266). This is how data become meaningful in answering the question. I looked for how the findings connected to existing themes and then asked if existing theory was being connected to other theory or if a new theory was being revealed. Looking for broader connections into society and global climate change and observing whether there were connections between what was going on in the mechanical engineering department and trends in larger society illuminated where change can occur in an industry that could have a large material impact on global climate change. Throughout this process I checked in with organizational members to see if the connections I was making resonated with those inside of the organization.

Finding themes is an important function in interpretation. Since this research question is so big, I looked for the less obvious and nuanced findings, surprises, and outliers. By using this method the researcher is free to let the data indicate the theoretical phenomena that are occurring. In this process I examined the nodes that had been identified in NVivo and saw if they could be combined into larger thoughts and how the themes were answering the research questions. Once the process of grounded theory had been accomplished and key themes were identified, I utilized Ellingson's (2009) approach to making claims, known as crystallization:

> Crystallization combines multiple forms of analysis and multiple genres of representation into a coherent text or series of related texts, building a rich and openly partial account of a phenomenon that problematizes its own construction,

> highlights researchers' vulnerabilities and positionality, makes claims about socially constructed meanings, and reveals the indeterminacy of knowledge claims even as it makes them. (p. 4)

Survey Analysis

Because the surveys offered data in the form of quantitative information, these data had to be looked at a bit differently than the other material. The surveys were used to gain an understanding of students' overall attitudes and beliefs about environmental issues and sustainability. Likert questions were analyzed to find the dominant opinions, so generalizations could be drawn. For the open-ended questions, qualitative analysis was used to identify themes. These answers were used to paint a picture of attitudes and not to report statistical evidence.

This process of data collection and interpretation was done with an eye on the final goals: 1) interpreting how participants were making sense of sustainability, 2) identifying contradictions in the socialization process, and 3) how actors use rules and resources to negotiate those contradictions. By speaking directly to members of that community, observing their practices and examining objects and written materials, I was able to get a good idea of what was happening communicatively in the department. Through coding and interpretation, I made sense of the data to draw conclusions about the communication practices.

CHAPTER 4

RESULTS

Research Question 1

RQ 1: How do the people in this setting make sense of sustainability?

To answer this question, the department's strategy for teaching sustainability and instruction techniques will be discussed. Next, data about how participants are learning about and making sense of sustainability based on survey responses, interview responses, and papers they wrote will be presented.

The purpose of RQ 1 is to give a broad-brush picture of the department and how sustainability and environmental issues are being conceptualized. This provides an overview of how the department and department members are making sense of issues surrounding sustainable design. Describing the department's strategy for incorporating ideas of sustainability, classes offered, and members of the organizations ideas toward sustainability displays the data used to infer and contextualize the contradictions that will be discussed in RQ 2. In addition, rules and resources available to this department will be identified and will be further explored. Moreover, understanding the individuals who are members of the organization helps the reader to understand the values and motivators for involved actors.

Department Strategy for Teaching Sustainability

This question will begin with exploring the strategies the department is using to incorporate sustainability into the curriculum. This section will begin with the perceived goals in the department and then will discuss the resources available to department members. The department's relationship with sustainability is complicated. There is not one agreed upon goal or focus for sustainability education. Faculty are given the opportunity to pursue a research agenda that includes sustainability, and the program recently hired faculty who are singularly focused on sustainability. Although not every professor in the department focuses on sustainability, and in fact a few think it is pointless, the department has made a conscious effort to hire individuals who focus on the topic. Resources are used to hire faculty who will teach and research topics of sustainability; having faculty as part of the department with this expertise demonstrates a departmental commitment to sustainability.

With that said, there does not seem to be an agreed-upon idea of how the department integrates sustainability into curricula. There is no explicit rule about how it should be incorporated into course-work. When asked what the department's goal or stance on sustainability is, no one could identify an agreed-upon goal or mission that the department had settled on together. One professor stated, "I don't know whether there is a department goal or stance on sustainability."

Professors and staff report that the department does not have an explicit plan about how to approach or teach sustainability. The department has indicated areas for which they have created a tentative idea for growth in teaching sustainability, but they have not held strategic meetings or planning sessions of how sustainability should be taught or incorporated into classes. Many professors stated that they felt there was an implicit value for the subject since so many of the professors' focus on sustainability is part of their research. This complexity of understanding is demonstrated in the following excerpts from interviews with faculty members:

> Dr. Harris: I mean, I think that sort of happens in the sense that we have a lot of people doing research in that area. I think that there's clearly a lot of people in the department for whom that is important and it just sort of pervades people's thinking. But there has been no clear communication that we are going to focus sustainability through all of our curriculum or anything. If there is such a stance or policy, it has not been communicated to me.

> Dr. Campbell: Well it's a mixed opinion. I think we all recognize the importance of it but it's not integrated very well into our core. There are some courses specifically dedicated to sustainability and we have an excellent professor here whose life is sustainability and so that's very valuable. I think in some ways we maybe missed the big picture in sustainability and we don't include it as that holistic big picture view so the students don't appreciate it as much as they could.

> Dr. Lewis: So we need to be thinking more long term of alternatives. Mainly I think about energy and where we get our energy, how we use our energy and so forth. We're all aware of this, so it's sort of creeping into our courses. But probably not by design. You know like, "Oh, we must do this" to put sustainability in the curriculum. It's just kind of a little shift in the terms of the examples we use, the way we try to tie it to what's going on in today's world. Okay this problem, this theory, this topic you're studying, here's how it's related so the things you might be hearing about, right? So that's really where the shift is incurred I think. We have, as I mentioned a couple classes at the elective level to deal with these in more depth. I think we're going to do more of that because we've just hired a new person whose research is on sort of global energy use, sort of building level, urban environment level…

> Dr. Petrotich: It's not identified from the top down. The dean doesn't, the department chair doesn't, I'm not sure we hear much of anything about it in faculty meetings, we don't talk about it, we don't ever have a meeting where we talk about reducing our energy. We never, none of that. I am just the crazy guy, but it doesn't seem to register on other people's minds.

These quotations demonstrate that although the importance of the subject is recognized there is no strategic way of addressing how to implement the content into classes. There are resources available to students who are interested in learning about sustainable design, though; there are no rules that require them to gain knowledge in this subject. At this point there are positive things happening in labs, elective classes, and faculty research at the individual and macro-level; however, there is not a holistic approach to sustainability.

This consideration of sustainability in the design process is a resource, the fact that it is being discussed and considered by the individuals in the department means that it is being considered. However, a rule does not exist that outlines what students will know about sustainable design when they leave the program or when and how that knowledge will be incorporated into classes. This creates our first glimpse of a contradiction; sustainability is understood to be important; however the specifics of how it is taught, who is responsible for teaching it, and in which classes it is discussed are not clearly outlined.

Classes That Incorporate Sustainability

Perceptions vary on how assertively the department should be incorporating ideas of sustainability into classes. There is a general understanding that sustainability is a topic with relevance to students' education and is important. Hence, some professors attempted to incorporate the concepts into existing required classes. The following section will describe existing classes in the Mechanical Engineering department in which individual instructors took it upon themselves to bring sustainability into the curriculum. Each of these classes that are offered can be considered resources that help actors within the system gain knowledge and information about sustainable design. This will help the reader understand how students are learning about sustainability in the program.

The LEAP First Year Learning Communities program is a campus-wide initiative to give freshmen the support and community they need in their 1st year to assure both success and retention. To help connect individuals with other students they will be sharing the undergraduate experience with, students are divided up by the major they are pursuing. The engineering LEAP program is called ELEAP (Engineering LEAP) and focuses on writing, teamwork, and sustainability. Because of the focus on sustainability, this is where many of the engineering students are introduced to sustainable design.

The ELEAP class is a course that each freshman can take in both the fall and spring of their first year of classes. In the ELEAP program students are taught the Brundtland Commission's (1987) definition of sustainability, but in the course of the class students are also tasked with creating their own definition of sustainability. The instructor of this class feels that having them create their own definition of sustainability enhances their exploration of the concept:

> Dr. Tolliaferro: The typical, as you probably know, the fairly standard engineering viewpoint is, "Okay, I'm given this bit of information, now I'm going to figure out how to satisfy the vision sort of thing." If you just spit out the definition, then they're like "Oh, I'm just going to not even think about it. I'm just going to fill in the blanks". What I try to do is get them to think a little bit about it. This way of approaching sustainability postulates that the concept is not just a simple definition to be regurgitated but instead is a complex subject to be debated and mentally wrestled with over the course of an entire education and lifetime.

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This assignment in ELEAP, creating a definition of sustainable design is how many students are introduced to the concept of sustainable design (as seen in Table 4.1). However, not every engineering student takes this class because it is not required. Moreover, 35% of the students who graduate from the program transfer in from other schools, so they are not at Mountain State University in their freshman year.

Although this is the first class where students are introduced to sustainability according to the ELEAP instructor, students spoke disparagingly of the ELEAP program due to the fact it did not teach the “hard” engineering skills. In fact during interviews with students, some talked about how they felt the subject of sustainability was forced upon them in the ELEAP class. This particular ELEAP instructor is trained as an environmental economist and facilitated lessons and discussions that allowed the students to explore ideas of sustainability in a very deep way. Because it teaches “soft” skills such as writing, speaking, and teamwork, the class is not considered by the students and other professors to be a part of the core engineering curriculum. Dr. Tolliaferro expressed that he did not feel that the students respected him as they would an engineering professor, and many engineering students said in interviews and interactions through participant observation that they felt it was a waste of time to take classes outside of engineering or from professors who were not engineers. The ELEAP class is seen more as one of the general requirements, not centrally important to the discipline of engineering.

On one hand, this course and the content it offers introduce sustainability to students. On the other hand, because it is presented in a class that teaches topics that are not valued as highly as others in the engineering program it is dismissed. The fact that the topic is explored within this class offers a resource, however; because students do not place import to the class, the topic is less valued than others in engineering.

Changes Adopted to Incorporate Sustainability into Curriculum

Some members of the department felt that sustainability should be highlighted more in the curriculum. Thus curriculum was changed to introduce the topic. To engage students in this subject more in a required class in the department, an emphasis on sustainability was added to the 2000-level design classes (ME EN 2500 Introduction to Sustainable Energy Systems Design I: Wind and Water Power, and ME EN 2510 Introduction to Sustainable Energy Systems Design II: Thermal and Solar Power). Traditionally at Mountain State University students were introduced to the concept of thermodynamics through two required classes. These are standard mechanical engineering curriculum in programs around the world. In 2008 the department received a National Science Foundation (NSF) grant to alter these classes and change the way that engineering concepts were taught in the first 2 years of the program to include lessons that would build upon each other (a curricular technique referred to as a “spiral”) while also teaching concepts of writing, teamwork, oral communication, and sustainability (Simmons, Sample, & Kedrowicz, 2010). The result of this change is the two classes mentioned above, ME EN 2500 and ME EN 2510. The main focus of these two classes is thermodynamics and design with sustainability used as the framework for the class. There are two projects that have to be completed by the end of the year that highlighted sustainable design: one, building a compressed air model train, and the other a research paper exploring a sustainable design process.

The model train project is an opportunity for students to design a locomotive that is air-powered. Here the students design in a more sustainable way by using compressed air to fuel the train. Because compressed air is an alternative fuel, the assignment is sustainability related. However, the sustainable aspect part of the design was never made explicit. Dr. Bailey described the project thusly:

> The big thing we've done is the design project in the labs. And you've seen the enthusiasm. It's a lot of work for the students. But they learn a lot from it and it's a real challenge. It's not explicitly a sustainability thing, but they're learning

> it, about compressible gases in this example. Maybe we'll do a solar one next.

Students tended to respond positively. Sam, a junior, said:

> We had the air-powered train. We had no emissions, we had a renewable energy source, and we had an engineering design. So all three of those are connected and while it's not explicitly said hey, look at what you're doing. You've got a no emissions design, that's a renewable energy source. I think every kid that worked on that can look at it and go, "Hey, we just linked all these things together."

Although the 2000-level spiral curriculum was a creative effort to incorporate ideas of sustainability, it has been criticized because although sustainability is in the title of the class and the students are assigned sustainability projects at the end of the semester, sustainability is not addressed the rest of the semester. As Dr. Lewis said:

> The intent was to try to maybe change the focus of those courses that had previously existed and the previous focus, and still the focus, is on numerical methods and thermodynamics. The idea was okay, let's take that content and tweak the examples and the homework problems and the projects so that they have more of a sustainability focus to them. I personally believe we have not done that.

The students agreed, as Dr. Taylor reported:

> So part of the problem in trying to put sustainability into that sophomore year is just that the students - oh you'll be interested in this little bit of data maybe - but so they felt like it wasn't part of the class enough. Like it just seemed like this extra thing we were tacking on and we made them write a big paper and they're kind of like "I don't have time to write a big paper. Why do I have to do this" type of thing.

The class frustrated both students and professors because it felt like a normal thermodynamics class that tacked on an extra sustainability writing assignment at the end. Sustainability then was and was not included in the course, this contradiction proved difficult. Because of the negative feedback and the end of the NSF grant, the class is no longer billed as a sustainability class and has gone back to teaching thermodynamics alone. When I interviewed the instructor who taught it in the fall of

2013, I asked if she had any sustainability aspects that she was going to incorporate into the class, and she said there were none. The spiral class was an example of a great idea that was difficult to manifest. It was innovative, and although a strong attempt was made to incorporate a great deal of material into the spiral classes, students and instructors found the large amount of content to be overwhelming. The fact that members of the department were willing to write the grant and create new curriculum identifies that the commitment to sustainable design education is a resource within the department. Because there was not enough time or money to keep revising the program and have it continue indicates a lack of resources to continue the vision of the spiral class. When the NSF funding ended, the class was dismantled and a more traditional way of teaching thermodynamics was adopted. The spiral model was an example of the department identifying that sustainable design should be taught but the implementation was difficult- one way of dealing with contradiction is to revert to the system as it was without the contradiction.

Senior Design Class and How Sustainability Is Incorporated into the Class

Because there is not a departmental plan to incorporate sustainability into the classroom, and the spiral model was dismantled, it is up to individual professors to create lectures in individual classes. A good example of a lecture being incorporated into an existing class can be found in ME 4000 (the capstone design class to be completed before graduation). An instructor interested in sustainability added a lecture about sustainable design to the class in the fall of 2011. Seniors said that the most they learned about sustainability came from the ME EN 4000 design class lecture on sustainability.

The lecture was received with mixed responses. John, a student described it like this:

> He brought it (sustainability) up and said, "Okay so I want you guys to do something about sustainability" and he kind of paused and made a little face and
>
> he was like "I hear some groans out there". I could tell, and I don't know what the follow up was, and it wasn't really overt but I could tell it was sort of like he knew that it was a buzzword and there would be grumbles. I felt like he had the responsibility in that moment to not say, "I hear some grumbles out there and that's funny". He didn't say that's funny but with his tone. I felt like he had the responsibility as an engineering teacher and a person with a PhD, to support. Be like, "Yes, it's a buzzword, I hear some grumbles and that's fine. It can be annoying. But on the other hand it's real and if nothing else, it's going to save you money as an engineer. It's going to save your company money if you can come in with a good sustainable energy or sustainable product idea. There's a really good chance it's going to save you money. It's becoming more popular and purely from a marketing standpoint, it's popular and people buy popular things." Anyway, so that was one. He wasn't super, overtly on either side, but I felt like there was a lack of a missed opportunity perhaps. Other teachers I suppose is sort of a spectrum, some I haven't heard anything, other like my sustainable energy teacher, he's obviously in full support and very scientific about it.

Although John felt that more could have been done, interview and survey results indicate that, for many students (14 of 58 responses), this lecture was the most that any professor had spoken about sustainability in any of their classes. Josh said:

> Obviously there's concern about it, but as far as it being directly approached in the department, there's only been one occasion and that's Design 4000 where that's actually happened, where it's been directly acknowledged and approached. Otherwise, what we're really taught to do is analyze the problem, create a solution that viable with the idea at the end that it makes money.

Two years later, another instructor teaching the ME EN 4000 Senior Design class was still unsure about his plans for incorporating sustainability into the course:

> I had some students come to me and they want to build what they call a kinetic, sustainability sculpture, which is basically just a sculpture which kind of gets energy from the environment and is just sort of intended to give the user kind of an interactive experience. It sort of demonstrates the conversion of energy. It's kind of cool. I think it really incorporates sustainability into that. A lot of projects have those things incorporated into them. When people come into the class, we go through a proper product and development and design process cycle. My goal in the class is to help them take their project and successfully complete

> it by following this methodology. If their project doesn't have anything to do with sustainability, we're not going to talk about sustainability much. If their project does, then they will. Really that's driven by what the nature of the project is in the first place.

This professor must have reconsidered because in the fall of 2013, he gave a lecture entitled, "Design for Sustainability" (or Design for Environment). This lecture started with placing the student in a timeline, stressing that others have come before and others will come after. The timeline illustrated that we are on earth for a small amount of time, and we have to think about perpetuity in the design process. The lecture then talked about the global footprint, life cycle thinking, and materials (where they come from and how you dispose of them).

The senior design capstone gave students the opportunity to explore ideas of sustainability. These lectures were touted to be some of the most informative that students receive in their undergraduate education. The senior design lecture about sustainability ended up being an important resource about sustainability for many of the students.

Electives Offered Regarding Sustainability

Although sustainability is not part of required core classes, student can choose to take electives that focus on concepts of sustainability. The following section will outline some of the sustainability-focused electives that are available to students. The class Sustainable Products and Processes is an upper level elective class that encourages mechanical engineers to think of sustainability as a foundational concept in the design process. Sustainable Energy Engineering focuses on collecting and saving energy that is harvested through renewable means. Thermo Environmental Engineers mainly focus on the heating and cooling of buildings and solar energy is addressed in the class. These three classes count toward the major's elective requirement. Engineering undergraduates need to complete a total of 128 credit hours, 12 of which are in electives, meaning they take four three-credit-hour classes. Around 25 electives are offered to undergraduate students. In the graduate program they have more flexibility to choose more elective classes, but because a master's program only requires 30 credit hours of coursework and half of those credit hours come from required core classes, even master's students have only five elective classes to fill. That provides an overview of what classes serve as resources for individuals to learn about sustainability. It also highlights that the department does have multiple resources available to instruct about sustainability. Students learn about the subject in the ELEAP program and elective classes. Additionally there is a willingness to try new things on the part of some faculty members who serve as champions for the issue of sustainability. The department is located within a university, and the next section will address what resources are available at Mountain State University.

Mountain State University and Sustainability

The mechanical engineering program is situated in a university that values sustainability. Mountain State University recognizes that sustainability is a concept that needs more focus at the school. In talking to the director of the Office of Sustainability, he explained the history of commitment to sustainability at the university. A former university president was one of 500 university presidents who signed the Presidents' Climate Commitment (PCC) a commitment to increase sustainability at the university. The current university president has maintained this commitment to sustainability. The

Office of Sustainability was created as a resource that oversees improvements to facilities, conducts outreach programs to students and community members, and pursues green initiatives on campus (Office of Sustainability, 2011). Additionally, through that office, the school is working on achieving its STARS (Sustainability Tracking Assessment and Rating System) rating. STARS is a system created by a network of universities so that progress toward sustainability can be quantified and compared with other institutions (Association for the Advancement of Sustainability in Higher Education, Initials, 2011). A fee is collected from every student on campus and is applied to a fund that supports projects on campus that will contribute to campus sustainability. The university's Global Climate Change and Sustainability Center coordinates research and projects centered on issues of sustainability around campus. The campus itself values the idea of sustainability and provides resources for students and faculty who want to learn about the subject. This organizational commitment to the concept of sustainability provides resources for individuals interested in sustainability.

The first part of RQ 1 has outlined the department and how it is strategizing incorporating sustainability into curriculum, what classes are available to teach sustainability, and what resources the university provides. The next section will discuss the individuals within the department to understand how members of this organization view themselves, their role as mechanical engineers, and how they view environmentalism and sustainability. This section will give the reader an idea of attitudes and beliefs organizational members have regarding these issues that will help to understand some of the contradictions in RQ 2.

Individuals' Motivation(s) To Become Mechanical Engineers

Before discussing how individuals in this organization identify with environmentalism, what motivated these individuals to become mechanical engineers in the first place will be investigated. This provides an image of what is motivating and inspiring these actors to pursue this profession, and how these motivations are related to sustainability. The individuals who are attracted to the job of mechanical engineer are often those who love machines, robots, and cars. The process of choosing what to major in is a process of self-discovery; often students are drawn to things that interest them. Through this process of selection, programs often attract people with similar interests who thus become a self-selecting group of people with similar skills, talents, and values. In interviewing students, professors, and professionals, a common narrative about how they became interested in engineering emerged: They loved cars. The following are excerpts from interviews expressing how automobiles and engines led them to this subject.

> Dr. Richards: I think I wanted to become an engineer because when I was a kid I was interested in Formula One racing.
>
> John: Well I had been going to college for a while. I was doing premed was my original goal. Then I just kind of lost interest and was trying to figure out something new. In that time period I bought a motorcycle and started doing stuff to it and then I just thought I really loved it and that's how I got the idea. I talked to a few people and just jumped in.
>
> Aaron: I like working hands-on, working with trucks, cars, building whatever. So I got into that program and one of my sister's friends, he was in the pre-engineering program up at Weber, and he's talking to me, he's like "You know what? You're an idiot for doing the MET instead of the ME Program". Same amount of time, but better jobs afterwards.
>
> Ryan: Well growing up, we had these go-carts, they were always breaking down and we'd take them out and I'd spend all weekend, I'd get them working, we'd take them out and they'd go like one lap and something would happen. I'd take my brothers and friends with me and they'd love it and race. I found that I enjoyed fixing them more than I did the driving. It wasn't so much the, okay,

> this part's broken, let's take it out, undo the bolts and redo bolts and fix it. It was, I don't have anything to replace this with. How am I going to make it work so we can still have fun today? So it was less a mechanic more of trying to engineer something. So I said, "Well yeah, engineering's probably for me."
>
> Sam: When I was 12 years old, I was on a dealer convention trip in California and I happened to take a tour through Honda's research and development department. While I was walking through there I saw what the engineers were doing, I saw the products and they had some new products that no one had ever seen and I thought that was really cool. It was at that moment that I decided I wanted to be a mechanical engineer. So that's how I decided that.

This connection between mechanical engineering and cars was also exhibited when I asked why students chose the senior design project they did. This student was reflecting on why he chose the Formula One car over other car projects.

> Ryan: I guess for one, I was looking at doing the Baja for my senior project and ended up going with the Formula because it was a much bigger engine, there was a lot more power, but there was also so much more to it, there was so much more you could change, a lot more freedom.

These people who love cars are drawn to research and study cars. Building and designing the kinds of vehicles that attracted these individuals to study mechanical engineering is not necessarily suited to the demands of addressing such issues as global climate change. One professor expressed this by saying:

> Dr. Petrotich: Right, right. Well that’s really interesting. One of the basic questions I guess, the first question is there's something different about somebody that decides to take on mechanical engineering that is not necessarily environment friendly. I think in a lot of ways, that's probably true. A lot of people that go into mechanical engineering are either gear heads or they're into bots.

This investigation of why people are motivated to pursue a field of study can outline some of the tensions between reducing carbon could be scary for those that love engines and combustible engines. Understanding why people are drawn to mechanical engineering begins to paint a picture of the actors involved and what factors play into them pursuing the mechanical engineering profession. Now that we understand the motivation of many of these individuals, how they talk about environmentalism and sustainability will be investigated.

Individuals Identifying as Environmentalist

Before an investigation of the contradictions occurs it will be useful to understand the multitude of values and knowledge that different organizational members have about sustainable design within this organization. Due to the fact that it is made up of many individuals with different beliefs and skills sets the stage of why it is difficult to speak of one value or one set of values for the entire organization. To help understand how individuals in this organization are making sense of sustainability, the following section unpacks and generalizes how individuals in this community identify as environmentalists and define sustainable design, cradle-to-cradle design, and the triple bottom line paradigm. I also used research papers from ME EN 2510 Introduction to Sustainable Energy Systems Design to examine how students are talking about sustainable design in school assignments. These answers help to get an idea of how participants are thinking about environmental issues and sustainability helping the reader gain context for the contradictions explored in RQ 2.

<u>Personal Definition of Environmentalism</u>

In building a working knowledge of the individuals involved in this organization a deeper more comprehensive picture and their motivations of organizational members can be known. Participants were asked about their knowledge of and beliefs about the environmental movement to see if they were opposed to environmentalism and sustainability or if they were open to the concepts involved. It turns out when asked if they identified as being environmentalists, almost all of them said yes which can serve as an important resource that may be drawn on as neophytes engage in the assimilation process. The only person who explicitly said he/she was not commented, “I'm trying to think of, like, any environmentalists that I know of that I relate to. I cannot think of one.” Among those who identified as environmentalists, the level of commitment ranged from a cursory interest to activist, and the term ended up being complicated for many of the participants. The following will outline the complexity of attitudes that organizational members have toward ideas of sustainability.

Most participants could find some aspects of environmentalism with which they identified. The following are examples of positive sentiments engineering students expressed about environmentalism:

> Ryan: You know, I love going outdoors, hiking around. It's sad sometimes you go hiking around and you see trash in the bushes and all over and it's hard to get to untouched area anymore. There's always something that's happened that has damaged the area and that makes me sad.
>
> Ken: Okay, that I can answer. I love nature. I love the pristine aspect of it and I think the less that we can do to harm that and to put a damper on that, the better. I mean, pollution standards for power plants. There's nothing we can do about China right now. They're doing their own thing, but I think we're on a good track for that and in the aspect of carbon footprint, sustainability, absolutely the environment is something we should be conscientious of and do our best to not further damage.
>
> Jeff: I think it's definitely an important part of what everyone should be thinking about. I mean, we're part of the world, we're part of a society and a culture and part of that is geography and where we live and trees and all that stuff and so we need to consider it. Yes, I am environmentalist in the fact that I love earth. I like the outdoors and I like being healthy, that's weird I know. So in that sense, yes I'm environmentalist and I think you have to, but I wouldn't if someone gave me a list of political things on the list, I wouldn't say, "Yes, I’m an environmentalist" like that's what defines me.
>
> Jeremy: yeah and when hiking and stuff like that then always picking up and leaving it better then I found it, that is really important

> Dewey: Yeah. My family teases me because I'm probably the biggest tree hugger out of all of them. I mean I'm not that much but I've just always been picking up trash as I'm walking down the street and just things like that. I like it. I mean, we're all kind of sharing this world and we all kind of take what we can get right now and then we're leaving whatever for the next generation. So I think that's important that we think of the people that come after us.

These individuals are concerned about the environment and indicate that they feel connected to the planet. Because they are interested in environmental issues, this could be used as a resource for those trying to bring sustainability to the forefront of the design process. By exploring how they are talking about their connection to environmentalism, some core beliefs about how environmental issues are advocated.

> Willard: I think there are a lot of good aspects to it, but I think people get carried away too far and go too far with it and ultimately lose any kind of value out of it because they push it too far.

> Aaron: I think it's a great idea. The problem I see with it is people are really environmental activists, they want everything done right now. For us to get to the point of right here, it took a lot of time and we built up different traditions, habits, to get where we are. To break those habits and just go to a different form, it's not going to be an easy process. If they were a little bit more gentle, I don't know if that's the right word, a little more persuasive without being aggressive, I think it would have a better outcome with them.

> Luke: It's like, let's see. I consider myself an environmentalist at heart, but I don't agree with the approach a lot of environmentalists have taken. I feel it's got to be done in a way where it were from the beginning the primary concern is people, not necessarily the environment. You preserve the environment for people, you don't preserve the environment for frogs.

> Cooper: As long as you don't push it too hard and you make people like me sour about sustainability. I like the idea…

This distinction among these answers provides an interesting contradiction that is navigated and managed in the organization to be explored in RQ2, a contradiction between feeling an affinity to the environment and not wanting to use the tactics associated with being an environmentalist. In addition to connecting with the actions of being an environmentalist, many interviewees expressed concern about being labeled a “hippy” or “greeny.”

> John: I am for environmentalism. I kind of think it has become a little bit of a, like I said, a buzzword where people hear it in an odd maybe political visceral reaction happens. I try personally not to use words like that as much as I can. It's interesting, when you talk about those exact topics without using the word, it's really funny to see the reaction of people who would normally if you say, "Oh, let's talk about sustainability" and they're like "Aw, hippie!" That's all they hear or whatever. But if you say "well let's save our company money and energy use" it's so obvious like "yes! Let's do it". That's all I know.

> Dr. Tolliaferro: Yeah. It's interesting because I think usually by - so I have the students for two semesters, which is nice because the first of the first semester they look at me as though I'm some green, liberal, out there telling them to stop watching NASCAR. Then by the second semester they finally learn that I'm not telling them to do anything one way or the other as far as that goes.

The concept of being an environmentalist ends up being complicated. Although the values and ethics that accompany it make sense to the engineers, the identity of being an activist or hippy is a bit harder. This will be explored further in RQ2 as individuals feel conflicted in their identity of being both a good engineer and an environmentalist. Now that environmentalism has been explored, this section will begin to investigate the concept of sustainability. This matters, because if members of this organization identify with being environmentalist, it is already a value that permeates other aspects of their life and incorporating it into the design process could be easier drawing upon that resource. However, if they are opposed to the values of environmentalist, that is a sizable hurdle to get over to bring ideas of sustainability into their work.

Another baseline environmental belief important to identify is students’ understanding of global climate change. Understanding of attitudes toward climate change, if participants believe it is happening or not can help to explain the urgency felt to design in a new way. To determine this, participants were asked if they thought climate change was occurring (Table 4.2). This line of questioning identifies that not only do many of the participants identify with being an environmentalist, 57% of the participants are fairly convinced (choosing "I think it is" or "without a doubt") that global climate change is occurring. Additionally, when asked if they felt that humans caused climate change, 47% said yes. This means that around half of the participants hold the belief that climate change is occurring. The prevalence of this belief should be considered a resource, as the belief is likely to both inspire actions and to contribute to a stronger culture of interest.

Limited Natural Resources as a Justification of Environmentalism

Another aspect of environmentalism that was not labeled as being environmentalism but did inform the participants' way of talking about sustainability was that many discussed the tension between the current way that products are designed and the natural resources available. Many participants stated that the current system of extraction and use is not supportable. Almost every participant observed that the process of design was going to have to change because of dwindling natural resources. They observed that due to a growing world population and the extraction that has been done in the past and present, limited resources were going to change the nature of engineering. They presumed that items designed will need to be more efficient and use fewer raw materials to be built. Several participants mentioned that a finite number of resources will impact the way that design happens.

> Dr. Bailey: Things are given the aspirations of the 90% of the people of the world, which they will want to have met. We're going to run across limited resources, so we're going to have to be more efficient is the answer, and more innovative. There are just going to be numerous opportunities for designing more efficient things and better things and ways of saving energy and reducing our carbon footprint and the automobile industry's going to be revolutionized in 20 or 30 years.

Students also mentioned the need to find new resources. Willard was willing to make some big picture suggestions on what should happen:

> No, I don't know. There is a problem - we don't have the resources to support this population. So either we need to find a new planet to go to, start restricting population growth, start mining asteroids for resources, whatever. Something big needs to happen. If it doesn't, then yeah, hello ice age, hello - the world will balance itself for us. But no, I definitely think that we have a responsibility to do something about that. Really that's the, what would you call it? That's the restraining factor I think is energy. The way that the government is looking at it right now is so much of it is focused on the oil industry that they don't want anything to change. Why would they support hydrogen fuel cells when so much of their lives are based off of everybody needing petroleum based products? Whereas, we need to go away from that. So although I have no experience in it, I love the idea of alternative energy sources, it may be something I get into on my own later, but that's got to be the next big thing or we're screwed. And that's the thing is like we can't wait until it's too late. We can't wait until the petroleum reserves run out, then we're like, "Oh what do we do?" We need to find a new energy source. Well you should have done that fifty years ago.

These participants are recognizing a macro-contradiction regarding natural resources, if design and production continue to occur in the same ways, dwindling resources will eventually become an issue. Continuing with status quo can only occur for so long, and there is a tension between a strategic, deliberate change in the way design occurs and forced change due to a shortage of resources.

Structuration argues the agent can have an impact on a system; however, these quotes would indicate that agents are feeling overwhelmed by and within the current system. This creates a contradiction in which the actor wants to take action but might feel that it is pointless. Professor Miller talks about the difficulty working in such a system.

> Dr. Miller: I mean like a bigger societal thing. I mean like policy decisions. Policy decisions and cultural societal things. We all drive cars, we all understand we can't drive cars forever, right? I drive a car to work every day. I know I can't do that forever, but the reality is there is no other good way for me to get to work that is reasonable. I mean I can take Trax, but it'll cost me more

> money and it will take a lot more time. So I'm not going to do that. I just think that most people are like me. I kind of think there's bigger structural things in our society that drive that.

Luke, a student, observed that only through changing systems will change happen.

> Luke: Yes and no. Maybe to a degree you can design things a little smarter, but I also think there's also a whole social aspect of this that it's not just an engineering problem. I think it really is a social problem that has to be attacked on a social level to a degree because it's, like I said, you have to build a product, but people have to be willing to pay to absorb the cost of the cradle to grave somewhere. If you're, as an engineer, you're worried about that as an engineer from the beginning and you have a product that costs so much people won't buy it, there's still a problem there. I don't see it just as an engineering problem, I see it also as a social problem. Until things change in a bigger way, they will stay the same

Often we hear about individuals who exclaim, “Why should I bother voting? It does not matter, my vote does nothing.” This feeling toward voting is analogous to participating in environmental change. People ask, “What can the actions of one person do in the face of environmental degradation?” I as an individual want to do things differently, but within the system it feels futile. It is a difficult place to be in, if everyone feels that his or her actions make no difference, then without doubt nothing will change. In RQ2, I will more explicitly explore this idea of lack of agency that permeates this study.

<u>The Importance of Environmental Policy</u>

Because individuals feel that singular action will not make a difference, there is a tension between the status quo of current policies and the desire for different ones. This is a large schism between what exists and the opportunity for a new way. These participants observe that the policies or how resources and rules currently exist are not sustainable for the long-term. As discussed earlier, some participants indicated the current policies are fine, while others feel that large systematic changes are required for things to be different. Large changes could occur as reflected by policy changes. This leads to a primary contradiction to be explored in research questions 2: Some participants indicated that current policies regarding sustainability were fine, but others thought that new policies needed to be created. There is a belief that people will do the right thing without governmental involvement or regulation; however, history has shown that is not always the case. A professor in the mechanical engineering department who is known as an advocate of sustainable engineering and does research specializing in the subject had some interesting insights on the need for policy changes:

> Dr. Petrotich: The good climate models are showing that it's going to be, could be bad and when you look at the worst case scenario that they projected back in 2006, 2007, we're on a track worse than the worst case scenario.
>
> Maria: Yeah.
>
> Dr. Petrotich: Things are not looking good right now. But there doesn't seem to be any outrage if you look at the state government…
>
> Maria: No.
>
> Dr. Petrotich: They're still pushing for fossil fuel development. You don't see a big push for renewable energy within this state. In fact, it's almost like its seen as a negative you know? It's clearly the deniers, that's part of it. So it is this communist threat they can't get over the fact that what we're talking about is very conservative sort of situation saying look you know, if you're going to have a population, we need to solve this problem. That's a part of it, but you know I think there are solutions out there. Clearly they're just out there. We just need to, as a society, recognize that we just have to make the sacrifices that I don't think it's a sacrifice. I don't think it would be much of one. I think life just gets better for everybody. There will be more jobs. It's kind of an interesting thing that's coming up - of course I'm involved with a lot of these other environmental groups out there and one of them has been this Mormon Environmental Stewardship Alliance. I've been working with them at the beginnings like that because I think it's a powerful voice to get citizens to open their eyes a little bit more in looking at it.

This quote demonstrates how some individuals are worried that there is confusion about who possesses power in this situation. Some neoliberals believe power lies in the environmentalists who have lobbied for governmental regulation enforced by the EPA and who also are fighting for sustainable designs and ways of generating energy. Others believe power lies in governing organizations such as ABET or the university administration. For example, one participant expressed that it is only through top down legislation that any changes would be made and even that will not be overly impactful:

> Josh: You know, I'm actually reading a book on that right now. I'm reading a book on eco-psychology, so that's an area I really started to focus my thinking now that I've had all this schooling within doing like social impact entrepreneurship and how to do sustainable engineering. This is the study like the human nature interaction teaches we do need radical change and I think it's got to come from the top down I think. We look at like this past week with Obama and some of the legislation he put through on climate change stuff with this asking the EPA to come up with some stuff around what the limits or caps would be on C02 emissions and pushing some of those renewable energies from federal lands. It's like probably one of the biggest pushes we've ever had from a president and from the government in pushing it. But at the same time, it's just kind of a joke because it's like it won't even make any sort of relevant impact.

Still others feel that the power is held though organizations with money and economic advantages such as oil and gas companies, large manufacturers, and corporations. These differing perceptions of who holds power -- those creating regulations and policy or those opposing regulation -- reveal a question that is unanswered and as such, a root of tension.

Although many engineers do not like to think that political issues are important to them, they do play an important role in engineering, especially when it comes to regulations. Many participants, when asked if sustainability would have an impact on their careers, noted that governmental programs would affect their jobs in the future.

> Willard: I think the political aspects of it will for sure. I really do. I think we'll start seeing more buyback programs and things like that. So it may not be directly related to global warming, but I would imagine that in some way, some political or lawmaking aspects will impact my career. And OSHA is a good example of where there's certain restrictions on manufacturing now I'll have to deal with that and questions about it.
>
> Maria: Do you think that global climate change is something that will have an effect on your career?
>
> Willard: Yeah. Because all these industries are getting taxed on emissions. Because of this, this paradigm shift toward that. So they're going to focus, I've heard they've been hiring more sustainability oriented engineers. And that's not my specialty. So it might hurt me a bit in the end.
>
> Allen: I still think that there's a bigger picture there. I think you need to influence the politics behind the people who are controlling the factories and the cars and the oil production on some level if you really want to try to eliminate the problem.

Some participants viewed these regulations and political agendas as a negative force in their careers.

> Luke: I think there are a lot of people with political agendas. I think there are a lot of people who want to use that to set up regulations and taxes. I don't think just taxing people will solve the problem. In fact, I don't think it's going to solve it at all. I think it's like that's one of the problems with environmentalism. You have a lot of people who are using it for their agenda so it kind of brings a dark cloud to the whole thing. Which I think it shouldn't, but I think it does because I think you have a lot of people who don't care so much about the environment as they do about their agenda, so it pushes people away from it. In my opinion, which is how I feel.

This expression of antiregulatory sentiment is not a surprise in the conservative state in which this study is housed. Participants who were antiregulation often argued that using policy to reduce the impact of global climate change was pointless, especially since it was a worldwide issue and any changes made in the U. S. would not impact other countries.

This tension between the macro-level policy creating institutions and how individuals made sense of sustainability were connected. Some organizational members expressed feelings that micro-actions made at a local level felt insignificant in the big picture.

Participants' Attitudes About Sustainability

To determine where students were learning about concepts of sustainability, the survey included questions about how students approached the design process, what classes taught them about sustainability, and how they defined sustainability. These surveys were completed at the end of the 2011 fall semester in required freshman, sophomore and senior level classes. The following information comes from students who completed surveys.

Understanding what students were learning about sustainability offered a view of how the subject was being presented in classes as well as what was (and was not) being presented. As makes sense, as the number of years in the program increased, the more classes to which the students were exposed contained ideas of sustainability. It should be noted that the seniors who were questioned took the 2000-level classes before the sustainability focus was incorporated, so they did not include that class as one of the places they learned about sustainability. The survey indicates that the ELEAP, the ME EN 1000/2000 spiral, ME EN 4000, and the elective classes are where students are learning about sustainable design (Table 4.3). Interestingly, a large percentage of students who were freshman and seniors indicated that they had not learned about sustainability in any class. This would indicate that the change to the sustainability-based thermodynamics class did enhance students' exposure to sustainability.

These answers indicate that information about sustainability was being taught in expressed the most incorporation of sustainability into classes. As students progressed in their education, they were exposed to concepts in more classes, but fewer students overall said the information was present in the courses they had taken.

Importance of Sustainability in the Design Process

To ascertain how important sustainability is in the design process, I asked what the top five aspects of design were as the engineering students were beginning a project (Table 4.4). This was to find out to what extent sustainability is one of the core concepts that students consider when designing. Survey results indicate that sustainability is not one of the top five considerations for students.

Table 4.4 indicates that although students have been exposed to sustainability, it is not one of the foundational aspects that they consider. Interestingly, safety is a design consideration that almost all students indicated was important. Currently, sustainability is not being linked to safety. Although clean air and water are issues of public health and contribute to the wellbeing of people, they are not usually explicitly framed as safety issues. I will elaborate more on this when I make suggestions of resources that can be used to encourage ideas of sustainability for teaching students.

The Many Definitions of Sustainability

Students were asked to define sustainability in the surveys. Results are reported in Table 4.4.The definitions center around the concepts of minimizing environmental impact, saving resources for the future, creating a design that is long lasting, and being energy/fuel conscious. This question was open–ended, and so I counted answers that were the same and most often mentioned. There was one definition of sustainability that was constantly given by students from every grade and program. This definition was

ELEAP, the 1000- and 2000-level spirals for underclasspersons. The freshmen "Meeting our needs without compromising the needs of our children and those in the future." This definition is the classic definition of sustainable development produced by the UN Committee on Environment and Development (i.e., the 1987 Brundtland Commission). This was categorized as keeping future generations in mind. This is the definition of sustainability taught in the ELEAP program that has been identified as one of the places where students learn about sustainability.

In addition to the surveys I also asked students and professors how they define sustainable design in interviews. The answers varied, but some themes presented themselves. These themes included lifespan of the product, energy used, and materials used. However, more participants indicated that it was a complex concept that was tough to pin down. The next section of this project will explore the multiple meanings and reactions to the concept of sustainable design that were presented during the interviews.

Individual Concepts of Sustainability

Because organizations are made up of individuals, the way that members of this organization are defining sustainability can offer insights to how the organization is managing the subject. Many individuals indicated that sustainability is a complex concept with many aspects. One answer to this question captures some of the multiple factors that go into defining sustainability. Ryan defined sustainable design as follows:

> Well in go-carting, it was anything that would last for more than three or four rounds. I run it because I enjoyed it more when things were breaking down, but it was still frustrating. You thought you had something working and then it only lasted five minutes and it was like, "Come on". For me, sustainable means it's reliable, it lasts a long time. But also, we've come to think about things like

> composite materials and things that are really light, really cool, but once they're done you can't melt them down and use them for something else. They're just basically useless and you've got to throw them away, there's nothing really to do with them. That also plays a part of it. Just something that can be reused once it's life is over.

Ryan alluded to an answer that many participants gave to define sustainability, which is that sustainability is the length of time that the activity or the product could last. One mechanical engineering professor said, “I define sustainability in that whatever activity you are doing, can be done forever.” Dr. Tayler made a joke: “Can I copy my answer from the students? [...] They just crack me up. They're like, ‘Oh yeah, sustainability. That's just like making it through this class. This class is so hard I had to learn to sustain.’” These answers imply that sustainability has to do with how long one can output the action they are participating in or how long an activity can be performed, either human performance as the above quote indicates, or how long a resource can be used.

Some students suggested another facet of this idea of longevity, emphasizing how long the product can last. Luke made some thoughtful comments about poorly made products:

> A lot of products now are made so cheap that it's also like you can talk about recycling too, but also to what degree are a lot of the products that we buy at WalMart? I mean, how long do they last? If you make just one toaster right and it lasts a hundred years, and I can easily see something like that happening versus a toaster that will last five years before it breaks for something stupid. Even beyond just recycling, if you just made a product right in the first place, but the toaster that's going to last a hundred years costs a lot more. There are so many different ways to approach it, but no matter how you approach it, the cost of it goes up somewhere and we just live in a world where everyone wants things dirt-cheap.

Along the lines of longevity are the lasting impacts that the product’s creation and impact will have on the earth.

> John: I would define it as something that is either neutral or beneficial to I guess life and the earth a ways down the line.
>
> Maria: Okay.
>
> John: Several generations. Whatever we do now, yeah…
>
> Ken: I would like to define it as being able to design something without leaving a footprint behind. You do cradle to grave design and you - how to explain this. I guess just being self-reliant. Being able to take what would be waste and put it toward good use, toward redoing your product.

So how long the product lasts and the impact it has on future generations is important, but as Aaron pointed out the materials used are also important.

> Sustainable design? That's a good question. I see it as being designing something that one, has a long life span and second, can use resources that don't require a lot of energy to mine them or attain them. Ideally doing like organic materials would be the best choice. But that's obviously not always the best choice for this type of field.
>
> Dr. Powell: Sustainability for one of course, is one obvious aspect of design is you don't want to build something out of material that is going to be harmful to the environment when it gets discarded. It would be nice if you didn't have to discard it, if it could be recycled. If you think about even the recycling process, is it sustainable? Is it as clean as it can be? I guess those are some of the things that kind of come to mind for me.
>
> Jeremy: OK, so the way I understand it is designing your product in such a way that all aspects of it are environmentally conscious so that would include minimizing the amount of waste material in its production, minimizing the use of materials that are hazardous or difficult to recycle.

The amount of time the product will last and the materials used have been addressed, but participants also note that the energy the product uses is important. One participant said, “I mean like everybody has their definition. For me in my field, as soon as I think about sustainability I think about renewable energy. So that's the first thing that comes into my mind, but there is much more to it.” The words “there is much more to it” are a good transition to the fact that it is difficult to make sense of sustainability.

Complexity of the Idea of Sustainability

The complexity of sustainability is demonstrated well by this description of a class project in ELEAP where the students have to establish and argue for if a product they design is sustainable or not.

> Dr. Tolliaferro "Then they can argue for or against it based on their technology. So part of what I'm trying to teach in the class in addition to sustainability, or probably even more so than sustainability, is constructing a good argument and critical thinking. I allow them to design this definition of sustainability and then they can argue that their technology doesn't satisfy it, which ends up being kind of interesting. In the same class you might have two electric cars. One team is saying they're sustainable and another team is saying they're not sustainable. They each have their different definitions so then they're able to argue whose definition is better or worse, which encompasses what aspects.

In this example a product such as an electric car is not a cut and dried, sustainable or nonsustainable product. This is a common criticism of the concept of sustainability. All of the aspects mentioned above -- materials used in manufacturing, length of time the product is usable, and impact on future generations -- are all part of sustainability. Because the concept is so broad, it is critiqued as not having any meaning.

> Dr. Richards: I think people agree that this is something that is not just like a new trendy - I say trendy, but I think it was there for a while. My only bag with sustainability is like the word itself doesn't mean anything.

> Dr. Miller: sustainable design …it's big and it's not well defined. So that's the only thing that I don't like with that buzzword is what is sustainability? So if you ask me a definition, if I had to on the street give a definition to someone, I would say "oh it's renewable energy."

> Ken: I don't know. I didn't get much out of sustainability's assignment.

> Allen: Sustainable design. I don't know. How do you define sustainable design? I think practically, honestly, it's kind of a misnomer right? I mean there is only so far we can go with sustainability. Ultimately there's a loss that's going to happen. I suppose the idea behind sustainability really is to minimize that loss as much as we possibly can. To the extent of do we want to be like the Chinese manufacturers and just have tons and tons and tons of hydrocarbon flying around all over the ground when we're done with every product run or are we going to try to recycle all of that material and use it for other things? Even though it's

> expensive, right? I guess that's basically how I see it, is to try to do the best you can. Try to be responsible.
>
> Maria: Tell me how you define sustainable design.
>
> Luke: I think it has to do with, I can't necessarily put a definition on it…But it has to do with designing in a way that it is environmentally friendly. I think that's pretty much what it is."

These comments are a good transition from participants who had a concrete definition of sustainable design and what that constitutes to those who felt it is difficult to make sense of sustainability. Jeff began his (eventually precise) definition of sustainability by clarifying how big the term was.

> Jeff: Sustainable design. I guess there are lots of different definitions you'd use, but I guess I'd say something that can be continued without or designing a system whether it's physical or organizational or anything like that, that can be continued without depleting either human or other resources.

Sustainability as Buzzword/Green-Washing

While some participants felt that the concept of sustainability was too big to define, others felt that the concept lost meaning because it is a buzzword or that it is green-washing.

> John: Again, same with the sustainable energy. That's why I applied for my current internship. I know that sustainability is kind of a buzzword but I am interested in it and I feel like ethically, for me, it's the best choice that could keep me interested in a job over the course over a long span of time.
>
> Cooper: Not the regulation. Just people are being controlled by like I said, the marketing people. They're just taking advantage of that. Which I can understand. Like "I want to buy a sustainable product" and it draws in this crowd that's like "oh, we're going to save the world" at the same time, you're drawing in people that are following trends and then you're following other people like the Timberlands, like rappers and stuff wear those, so they're going to buy it regardless. So just attracting all this new attention. It's just a new concept of throwing on a marketing plate honestly. They don't build stuff like they used to anymore. I don't know if you remember all that stuff like Frigidaire. I think Frigidaire is the best example, that stuff lasts forever. I've still got one running.

It is worth the money.

These participants seem to view the concept as a marketing term or as a term that has no meaning.

Sustainability as a Political Concept

Similar to that line of thinking is the idea that sustainability is a concept and a word that is too political for the subject of engineering, which tries to stay away from controversial social subjects and instead focuses on math, physics, and physical science. One professor who was the first to incorporate ideas of sustainability into ME EN 4000 described what it is like to teach about sustainability in class.

> Ebert: There's such a bipolar, political and even scientific viewpoints on the topic, we see the same in our students where maybe it's the wrong word, but unless they've been indoctrinated with one side or the other, they're kind of okay, it's just another topic. They've heard it, they've seen it. But if they have had that indoctrination on one side or the other, whether it's positive or negative, we definitely see that come out in the reaction to talking about it. It's important, maybe they don't appreciate what it means to them as an engineer, as a designer in what they'll do as they graduate. Maybe I just need to do better as a faculty to give them that picture.

Finally there were some participants who felt that sustainability is a topic not worth considering in an engineering program. In one interview with Professor O'Malley, when I asked how he prioritizes the concepts he teaches in his class, he said:

> I don't include anything about sustainability. I don't even think I have ever mentioned that word in class. I think it's a hype word. So how do I prioritize? I have my syllabus and I try to follow my syllabus and I stick to the plan what I've prepared. But there is not really any need for prioritizing because I just follow my entire lecture plan and give all the information to the students.

When I asked him why he thought it was hype he said, "It just seems like everything has now an aspect of sustainability involved in it and I don't see how that's relevant to the classes that I'm teaching." It is interesting that he identified that everything has some aspect of sustainability but the idea had no relevancy in his class.

Conceptualizing Space and Sustainability

Another aspect of sustainability that participants identified was a feeling of powerlessness and a lack of agency due to perceptions that it did not matter what actions individuals in the United States took because if the rest of the world took no action (especially China) global climate change would still be a threat. The following students are making sense of a large global system in which the perceived lack of environmental policy from China makes them feel that action taken in the U. S. is pointless:

> Ken: Okay, that I can answer. I love nature. I love the pristine aspect of it and I think the less that we can do to harm that and to put a damper on that, the better. I mean, pollution standards for power plants. There's nothing we can do about China right now. They're doing their own thing, but I think we're on a good track for that and in the aspect of carbon footprint, sustainability, absolutely the environment is something we should be conscientious of and do our best to not further damage.

> Sam: My personal opinion is obviously entropy is being generated every day. Any time we breathe, every second we're alive, we're giving off heat. Entropy is being created. So yeah, the earth is definitely seeing an increase in heat and an increase in energy capacity, which would lead me to believe that there is a global climate change taking place. To the extent that some people say it is, no, I don't really see that happening. A lot of people stand on the side of we're absolutely just destroying the earth and a lot of times what happens is we Americans want to take care of that and we're trying to fix that, correct that. Well we're a nation of 300 million. We are a drop in the puddle compared to the world's populace. But we ultimately hurt our economy trying to correct this while we have major countries like China and India who don't care and populace's of one billion plus. Well they're not doing anything. So I think the key to getting global climate change dampened would be to get all those nations on board with our kind of mission control regulation. So I think that would be a big thing in taking a step toward getting climate change dampened. I feel like the U.S. has done a really good job at putting regulations in place that do help and reduce emissions and carbon footprint. But at the same time, they've put some stuff in place that really hampered our economy. To what degree needs to be fixed obviously there's middle ground that you can really strike a good balance between getting things

> clean but not destroying your own economy. But we need to get those other countries on board to meet that. But like I say, I do believe that there is some form of climate change happening because there has to be. There are a lot of us living on this earth now and there's a lot of entropy being generated because of that. So yeah, it's definitely something that is of concern to us mechanical engineers and absolutely we consider it. Like I say, what is the extent we need to consider it too? And how can we get these other countries on board with our considerations?

> Luke: I think it absolutely might. It will have an impact on a lot of careers. I think for the most part, it's going to have a negative impact on a lot of careers in the United States because something's got to be done in order to also allow the companies to still be competitive because there's also an element that the companies still have to be competitive to companies that don't care, like China. They don't have a lot of the regulations that they have here in the U.S. Maybe they do; I don't know. But I don't think they do.

This simplification of policy development is the strategy that these participants use to process complicated environmental problems. These respondents pointed to bigger structures that seem to be untouchable by the individual actor. It seems that an engineering undergrad in Mountain State would have very little influence on sustainability given the larger structures negotiating sustainability.

The complicated environmental issues China is facing as unprecedented economic growth is occurring and the need for energy and resources occur is an interesting focus for participants to point to. It is a set of systems difficult to process and understand, and China is having as much difficulty creating comprehensive environmental reform as America (Freeman, 2009; Wu, Deng, Huang, Morck, & Yeung, 2013). The fact that multiple students have opinions on how China's environmental policy impacts the world environment when previously it has been stated that engineering classes do not cover such topics is interesting. These are not necessarily informed opinions. However, they do underscore how participant accounts resonate with contradictions posited by structuration theory.

Academic Concepts of Sustainability

Another way to identify students' understandings of sustainability was to ask students to identify two common concepts of sustainable design. The first survey question asked the students to identify the 5 Rs of sustainable design. The second asked them to define "triple bottom line." These two concepts are the foundations of sustainable design Elkington (1999) introduces. The purpose of this is to find out if the students are being introduced to these ideas. If they do not know the answer it indicates that concepts have not been part of the curriculum or if they were, they were not remembered. These survey questions were meant to create a picture of the way the mechanical engineering department is talking about sustainable design from the perspective of newcomers. The five Rs are reduce, reuse, recycle, replace, and reinvent. The concept of triple bottom line is that companies could change the idea of business success to include three outcomes: profit, people, and planet (Elkington, 1999). Answers that were also considered appropriate were economic, social, and environmental. The top answers that students gave to this question are listed in table 4.5.

These results indicate that students do not start the program with an understanding of these concepts; it is being introduced to them in classes. These results do not explicitly state where they are learning the concepts, but it appears to be in the spring of the freshman year or fall of the sophomore year. This makes sense as the ELEAP class taken freshman year focuses on defining sustainability.

Sustainability in the Personal Lives of Students

As these individuals make sense of sustainability, it is important to point out that most of them value sustainability enough to incorporate it into their lives outside of engineering. In the surveys I asked, “To what level is sustainability important to you in your personal life? The answers are demonstrated in Table 4.6. The majority of the students rated it important, very important, or extremely important. This indicates that this is a topic that is important to these students and something that they pursue outside of their academic life.

In spring 2012, 64 sophomores participated in the first offering of ME EN 2510 Introduction to Sustainable Energy Systems Design II: Thermal and Solar Power, the final class in the four-semester spiral. A component of the class was to write a paper about something to do with sustainable design. The assignment was introduced to the students as a way to help them explore an aspect of sustainability and mechanical engineering of interest to them. To encourage invention and exploration, the assignment was open-ended in that they could explore almost anything ranging from green power to using recycled materials in the construction of devices. The assignment was previewed through providing a rationale for the importance of sustainability to engineering by linking sustainable economies to business and innovation. Specifically, students were asked to write a 1400-1800 word research paper where they examined a focused issue related to sustainability and engineering. At least five academic sources were required.

Overwhelmingly, the students’ self-selected topics related to energy and transportation and framed sustainability as important to meeting the demands of an increasing population dependent upon nonrenewable forms of energy. Even though defining sustainability was part of the assignment, many of the students did not provide a definition of sustainability in their papers. In fact, 39% of students did not provide a definition in the paper. Other students seemed to express confusion about the topic. For example, one student wrote: "In today's world there is ever-increasing talk of sustainability. However, the term 'sustainability' can mean many different things depending on what you are talking about and who you are talking to." This student expressed that even though she/he has heard the word sustainability, she/he is not familiar with exactly what it means, and more particularly, she/he does not offer a definition of sustainability that links engineering with responsibility in the design process. This reinforces the complexity of the concept as demonstrated in interviews.

A few students did, in fact, provide more robust definitions of sustainability that included ideas from the Bruntland commission or concepts such as cradle-to-cradle design or the 5 Rs. An example of such a definition could be found in one student's description:

> The philosophy of sustainable design is one of designing objects, including environmental projects and services to comply with the principles of economic, social, and ecological sustainability. Sustainable design is expected to eliminate negative environmental impact completely through proficient, perceptive design.

This definition was impressive because it encompassed the concept of triple bottom line and linked it to design. In short, results show significant variation in definitions.

Much like the interviews, these papers make it clear that students have a wide range of opinions and ideas about sustainability. These results support the finding that this is a complicated word that brings a range of contradictory responses or opinions. It is also clear that although this paper was at the culmination of the spiral experience, sustainability was not a clear concept to the student after a 2-year process.

The intent of RQ1 was to give the reader an overview of the department, its stance on sustainability, and some insight into how students conceptualize ideas of environmentalism and sustainability. This department is coming to terms with how sustainability is part of the curriculum. Additionally, by looking at how individuals define sustainability it can be understood that individuals create this organization, and these individuals define and conceptualize sustainability in many different ways, creating a complex understanding of the topic. In general most faculty and students acknowledge that sustainability needs to be part of the socialization process and that it will prove to be part of being a practicing engineer. This has inspired the department to take action to include sustainability into the curriculum. Sustainability has been incorporated into the ELEAP program, the 1000/2000 level spiral program, and ME4000 senior design. Additionally, faculty who focus on sustainable aspects of engineering offer elective classes that build expertise for neophyte engineers.

Opinions about environmentalism, climate change, and sustainability were diverse, but the majority of participants identified as conscious about the environment on some level. The definition and attitude toward sustainability was more complex. It had a variety of meanings for participants ranging from conserving resources, creating a long lasting design, using energy saving techniques, and minimizing environmental impact. Many were concerned that it is a buzzword and did not have a tangible meaning. When asked to define some of the concepts and how they are applied to the design process, some were familiar, but the majority was not. It is a department that understands the importance of the subject and is grappling with how to incorporate it into the course of study.

Research Question 2

Research Question 2: What are the contradictions (macro and micro) and how do they manifest communicatively within the socialization process of novice mechanical engineers? How are contradictions managed and negotiated within this site?

- How do actors use structures (rules and resources) as they negotiate the contradictions?

The purpose of RQ1 was to provide an overview of the department and how the people within it are conceptualizing and interacting with ideas of sustainability. To demonstrate that information a picture is painted with the data. Because RQ2 has a different task… identify the contradictions, this answer is presented in different format. Whereas participants were asked to describe how they saw sustainability fitting into the department, that question could be asked in a straightforward way and reported in a straightforward way. However, to identify contradictions, participants answered questions or observations were made and conclusions were extracted from that process.

To accomplish this, findings are organized by first looking at macro-level institutions, which include time and capitalism. Within these macro-level contradictions, mid-level institutional systems will be identified and linked to the macro- contradictions; these are units such as Mountain State University and the field of mechanical engineering. Then organizational contradictions will be identified, specifically the Mountain State University's Department of Mechanical Engineering and the actions of its participants. By identifying where the contradiction is occurring within these layers of society and observing how each contradiction impacts the next on every level a more nuanced view of the contradictions will be explored. Because these contradictions do not exist in a vacuum the interplay between the macro-, mid-, and micro-level contradiction will be linked.

As Engeström and Sannino (2011) claim, the concept of contradiction is rather broad. Thus for contradictions to be useful, they must be clearly defined and narrowed down as much as possible. Specificity is important; hence, findings will be organized in such a way as to create a map illuminating where contradictions exist. Giddens (1979) defines contradictions as "disjunction of structural principles of system organization" (p. 131). They are the fissures in systems and structures where inconsistencies exist. By examining these contradictions, sites that could be interesting sites for change can be identified. Contradictions will be identified at multiple levels of society. The first level of society that is going to be investigated is that of macro-level institutions. These are the overarching entities that impact how an engineering student at Mountain State University is socialized to incorporate sustainability into the design process. These structural contradictions are those that happen at the broadest level of society. The contradictions occurring at the mid- and micro- system level will be investigated within these two contradictions, allowing the reader to see that these contradictions are manifesting at every level.

The use of primary, secondary, tertiary, and quaternary contradictions will help to clarify the contradictions further. By classifying where the contradictions are occurring, how they interact with each other, and specifying what kind of contradiction they are, this study will serve as a precise locator of where change could be most effective. This method of reporting findings allows the reader to locate an exact point in society and type of contradiction that is occurring. The strength of SAT is that there are linked oppositional tensions embedded in deep structural oppositional tensions, and they are manifested in particular ways. The intended goal is that this identification leads to a clear diagnosis of an intervention that could be tailored to the contradiction identified.

Time: Climate Change Demands Time Urgency and Bureaucratic Structures Move Slowly

The first contradiction to be explored is time, specifically, the contradiction that is created between the urgency of climate change and how the process of carbon building in the atmosphere is in direct conflict with the slow moving academic schedule. Climate change needs to be addressed now, however the slow moving schedule of academic bureaucracies makes curriculum, policy, and departmental changes take a great deal of time. This becomes a classic example of a secondary contradiction, which

> become evident between system elements when new elements are introduced into the activity system (Engestrom, 1998). Secondary contradictions are tensions between two existing elements of a system that cannot be resolved without transforming system elements and practices (Canary, 2010, p. 187).

Identifying time as a contradiction is an interesting way to explore how long change takes to manifest in a university.

Historically it does not happen quickly, and the urgency of action needed to mitigate the effects of climate change is very much present, especially with regard to how new engineers need to change the way they approach design. It serves as a secondary contradiction because the conceptualization of time is in contradiction. The slow system of academia, developed over hundreds of years, is not adequate for the issue of climate change. Traditionally, new ways of thinking are debated, deliberated, and considered carefully, taking years to implement. Knowledge creation is a slow process going from a hypothesis, to studies and experiments, to publications, and finally to including new ideas into introductory curriculum. The process takes years. The contradiction that is illuminated here is that because CO_2 is being released now, and the current way of designing machines sanctions this output, expedited change in the way that design is approached needs to be adopted as soon as possible. The luxury of slowly integrating new ideas into classes does not exist. Global climate change offers a timeline that makes the existing system of slow change in academia problematic. Instead of time being an infinite resource, it is limited.

There is a contradiction between the existing relationship of universities to time and natural time, which demands changes be made with the urgency of global climate change. Orlikowshi and Yakes, (2002) discuss that time is experienced through organizations and can be viewed as objectively separate from the man and subjectively, as socially created. This is the crux of this contradiction. The university schedule that is socially created versus the time-frame of nature, or climate change. Professor Petrotich stated:

> If I want to look at you know, what really scares me about sustainability is global warming. It's immediate and we've got to do something about it. Our society is based on such waste, it just drives me crazy to think we're doing all these stupid things and we're trying to turn a corner and not be such a disposable society.

Many of the participants mentioned that organizational change is a slow process in academic institutions. Time is a resource, and currently the way that it functions within the academic structure it is in contradiction with the actions that need to be taken with climate change. Time cannot be both an unending limitless resource and a limited resource concurrently.

Although there is a pressing need for dramatic change, especially in the arena of mechanical products, the university system is slow to move. This contradiction is observed at the organizational level by professors that are living with this macro-level contradiction of time. Many professors mentioned how long and difficult change was in an academic department:

> Dr. Bailey: It's like getting faculty to change, right, in a tight curriculum where you have experts in the field and they've got their classes set up and we've got the curriculum set up and it's jammed packed full already for the students. How do you add something different? That's part of it. That's probably it. I don't think that there's any, I think probably a lot of the faculty are very much in favor of it, but it's so tight and it did involved a lot of change and it would involved a lot of time and so I think there's just that implicit graveyard resistance. One of the more famous presidents of Harvard from years ago, must have been in the '60s, I forget when he was president. But he was asked about making major changes in the curriculum at Harvard. You know this quote? Then he quoted something to the effect that well, "making major changes in academic programs at a university with the faculty of the university is like moving a cemetery." Very difficult. And people don't get involved right? The bodies involved, don't get involved.

Another professor addressed how reluctant the faculty is to change curriculum.

> Dr. Lewis: I suspect we'll be making some changes as a result of how things have been going as well as some of these outside forces that we didn't really pay attention to when we implemented this program. Which are costs, faculty buy-in to teach these courses? They're different and so we have some advocates who are supportive of this curriculum but then we have other faculty who say, "I don't want to teach that curriculum".
>
> Maria: Yeah. That's tough.
>
> Dr. Lewis: That's tough, right?
>
> Maria: Yeah.
>
> Dr. Lewis: It's nontraditional and change is difficult.

This contradiction between alternate timelines is identified on the macro-level, in the process of the academic schedule. However, it is being lived and experienced by organizational members at the macro-level in this department. This contradiction is negotiated through a reluctance to change on the part of individuals because change will require more resources that are not available to professors such as time to create new course content. Institutional pressures make it difficult for big–picture, structural issues to be dealt with; the day-to-day has people overwhelmed. Faculty feel that the program is already struggling to get all the information necessary into a 4-year undergraduate program and could not be expanded due to time restraints. Other than the discussion with Dr. Petrotich, no participant mentioned the pressing timeline of global climate change.

Almost every professor with whom I spoke said they would love to include content that broadened the students' thinking, including more biology and biodesign, more social issues, ethics, and sustainability. However they felt hard-pressed to cram the current curricula into the short amount of time available. One professor who is actively involved in trying to get more ergonomic safety included in the curriculum drew a parallel between his attempts to have more emphasis on safety in the curriculum to more emphasis on sustainability in design.

> Dr. Miller: In mechanical I think we have as much of a problem as any in that there's more and more things that we want our students to know. But, we still are stuck with a four-year curriculum. Europe has a five-year engineering curriculum. We have a four-year curriculum. We're trying to pack more and more into it and still trying to keep some liberal arts, some of the other humanities type courses in the curriculum. It's just getting harder and harder.
>
> Dr. Ebert: In sustainability, people are really passionate about the topic, but no one knows how to do it because there's so much that has to be gotten through in the four years that an engineer's here. The physics and the science and the safety stuff. How do you get that holistic idea of humanities. You're right, they're big discussions, they're big philosophical discussions that as a culture we're having. How do you manage them when you already have a jammed packed hardworking student body and teaching staff that is strung out? It's tough. Already there are things we omit in our engineering curriculum, like statistics, we don't have formal statistics instruction. Yet if you analyze any form of data, you need to have some foundation in statistics. So it's hard to replace something with something else in weight, whether it's better or worse or more important or not in some other topic.

Many of these individuals understand the value of sustainability as a subject, but the busy curriculum makes adding new content difficult. The department did try to negotiate this by creating the 1000/2000-level spiral class that would integrate ideals of sustainability into existing curriculum. This was an innovative idea, but because the professors were already overextended for time, creating a curriculum that would speak to the technological and science skills that needed to be gained and would provide knowledge about sustainability and teamwork, the class did not come together in a coherent way. Although the name of the class changed, the content did not. This ended up frustrating students and professors who did not feel they were doing justice to the subject. The attempt at changing the class has been considered by students and faculty alike an intervention that did not work, and so the class has returned to its old curriculum. This leads to the next discussion of why change is difficult: that people are overextended for time to change the way they do things.

Structuration enables an understanding of these complications. The large change that is desired is to cut emissions as to reduce the impact of climate change, a macro-structural change. However, the university system and more specifically, this department moves slowly. The macro-idea of the knowledge building process impacts the university system, and the individuals within it. Hence new ways to teach mechanical engineering are slow to be implemented.

The curriculum and the need to include a great deal of content in 4 years are being shaped by two factors. First is the ABET process and the next is that newly minted engineers need to be able to be prepared for the job they will be taking. These are both contradictions that appear at the mid-level.

ABET as a Foundation for Engineering Education and Disregarded While Creating Classes

The contradiction is that ABET requirements are created as a resource but perceived as a nuisance by members of the department. This contradiction exists between a mid-level institution (the ABET governing board) and individuals who design classes within the department. It is categorized as a mid-level secondary contradiction but effectively demonstrates the interplay between organization and mid/macro-level institution. Secondary contradictions exist between two elements that occur in a system and cannot be resolved without one or both of the elements changing. In this case the elements are ABET standards and the way professors create curriculum for classes. ABET creates standards for engineering departments. However those are not used as guiding forces by professors as they design classes.

ABET has created a national standard of information that each engineering student should possess before they become professional engineers. It fits into the overarching contradiction of time, because the ABET requirement helps to identify what information and skills need to be learned in the process of attaining an undergraduate degree in a 4-year time span. The requirements are determined by asking professional engineers and scholastic bodies what skills they need to be successful in the profession. Each school that is accredited has to go through recertification every 6 years to make sure that these requirements are being met. The requirements are as follows:

> General Criterion 3. Student Outcomes
> The program must have documents describing student outcomes that prepare graduates to attain the program educational objectives.
> Student outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program.
> (a) an ability to apply knowledge of mathematics, science, and engineering
> (b) an ability to design and conduct experiments, as well as to analyze and

> interpret data
> (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
> (d) an ability to function on multidisciplinary teams
> (e) an ability to identify, formulate, and solve engineering problems
> (f) an understanding of professional and ethical responsibility
> (g) an ability to communicate effectively
> (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
> (i) a recognition of the need for, and an ability to engage in life-long learning
> (j) a knowledge of contemporary issues
> (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (ABET accreditation, 2013)

Requirements c, d, f, h, and j deal with broader societal and ethical issues and requirement c explicitly states that sustainability should be considered in design. In the accreditation process, programs have to prove they are fulfilling these requirements. When attending the American Society of Engineering Education 2011 national conference, I observed that the “soft requirements” were often referred to as “the c-k”. These requirements were joked about as being the “lesser parts” of engineering education, and within the hierarchy of engineering education, ranked lower then the “hard skills” of math and physics. Although all of the requirements are needed to be accredited not all of them are valued equally.

In a correspondence with an ABET accreditor, she stated that most programs fulfill these requirements with a large senior design team project that requires students to work together and make presentations. Additionally, if programs offer classes that provide the information needed in the requirements even as electives, they will be accredited. ABET goes through a great deal of work determining what employers are looking for and creating standards that programs need to meet to fulfill those needs. Preparing students to be ready for industry is the goal of ABET, and thus programs that offer those skills are meeting the goal.

As far as meeting requirements for accreditation, Mountain State University mechanical engineering program is doing a fine job offering students exposure to sustainability through electives. The department is currently committed to keeping ABET accreditation; however, the requirements of ABET do not impact the course creation process for many of the individual actors constructing coursework.

Multiple professors said that the ABET criteria were not a consideration as they created and taught their classes:

> Maria: My next question is about two of the specific requirements. They are listed alphabetically. Both C and H ask pretty big things basically. The ability to design a system component and process to meet desired needs with a realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability and just understanding the broad impact of global economic, environmental, social context. How do you get these things into your class?
>
> Dr. Richards: I'll be honest with you; it's not necessarily included in the class. Yeah to be honest, it's not something that when I'm teaching my classes that I account for.

One professor who has been actively involved in the accreditation process gave a good explanation of how ABET came to be and why it may be in danger in the future for some departments:

> Dr. Bailey: Everything was science, science, science in order to make engineers better educated. It just ignores a lot of practical things that 70% of our graduates need to have; or 70% roughly of our students will go onto industry and another 30% will go to graduate school and then go to industry. They need certain skills and knowledge. So that was being ignored and that's why ABET came along. It's still needed. There's a strong emphasis here in this college now to get money, money, money so that you can do high level research. So I'm a bit worried that there's a bit of a trend against ABET here because it's a conflict that you see at any research university. You've got research needs and you've got teaching needs. To do research, you've got to get a lot of money to do teaching really well
>
> you've got to spend a lot of time. And those are the fundamental conflicts I'm sure you'll get to someplace here.

This quote demonstrates the contradiction that exists between the process of accreditation through ABET and how the contradiction is being navigated. Instead of using the standards as a map for creating courses and assessing what standards could be weaved into the coursework, such efforts are constrained to the year of accreditation, in which evidence of standards being met is found in coursework gathered from students for the prior 6 years.

This contradiction highlights ABET, a governing organizations created to design a universal set of standards for universities. This enables industry to hold expectations for individuals who graduate from an accredited program. Graduates from an accredited program will possess a uniform set of skills, values and understanding of the profession. It is essentially a body that ensures that new engineers are socialized in a manner that is sanctioned by this governing organization. Although programs have to adhere to these standards, engineering professors do not necessarily consider these standards when creating curriculum. The implicit message of ABET's objectives is that it takes more than technical skills to be an effective engineer. These accreditation objectives become a contradiction as they both are foundations for an engineering education and disregarded creating classes. This contradiction demonstrates the interplay between macro-, mid-, and micro- levels of organizations.

Traditional Teaching of Mechanical Engineers in Contradiction with What Future Engineers Need to Know to be Prepared for Careers

The other mid-level contradiction within the larger contradiction of time is the multitude of skills and knowledge that new engineers need to know to be proficient for the jobs of the future. It is a contradiction between the training of past engineers and the training necessary for engineers of the future. New information necessary for the job means more information to provide into a 4-year curriculum. This is a mid-level tertiary contradiction: The contradiction is that what made a well-trained engineering student in the past is not the same as what a mechanical engineer will need in the future. Tertiary contradictions occur when a more advanced element comes into an activity. In this case, that is the new knowledge necessary to being a well-prepared engineering graduate as opposed to the traditional knowledge required for past engineers. The field of mechanical engineering is changing and what is currently regarded as important knowledge for an engineer is shifting. New engineers will require a broader base of knowledge in the future. However, even though new knowledge is required, the material that is currently covered is still important and needs to be taught. This next section will discuss how individuals understand the necessity of teaching sustainability. This will mean a change in the way knowledge building is approached. It is an exhilarating time and many of the participants agree that society is at the precipice of some exciting changes that engineering will help facilitate.

> Dr. Lewis: I think that if you look at the big global issues, that's going to drive the future for the discipline. Environmental issues, sustainability certainly, but quality of life, environmental issues like air quality, transportation is always going to remain, we're a mobile society, so we're going to continue to work in that area. Energy production, we're less invested there but we will become more invested I think in solar and wind and perhaps geothermal. Think about oil and coal. Those are primarily chemical engineering. Those resources are being depleted so you may see a shift in terms of engineers in the energy industries maybe more to mechanical; particularly with wind.

This quote encompasses that previous thinking mentioned that resources are limited and because of that, it is necessary for the way that students are taught to change. Additionally, students need this information to be competitive in the field.

Dr. Richards: I think probably the way we teach mechanical engineering right

> now, like it's probably not super appropriate because we still teach in the old concept and the old ways. There was a buzz in the beginning of 2000 and everything was nanotechnology. So as soon as you were saying nanotechnology, you were receiving a grant. Now in nanotechnology, I think it's just part of our life, part of our, we don't see nanotechnology because it's just part of everyday life. So I think that mechanical engineers will have to deal with that. Basically dealing with things at the nano-scale have that for a program right now is really for that. So I think this is where it's going. Everything is becoming a little bit smaller. Yeah, I feel that my students, if they're looking for jobs, I feel that there is much more job in this renewable energy technologies. I feel that everything related to propulsion or combustion, I feel like this is going down like crazy.

Professor Richards specializes in nanotechnology. He uses it as a metaphor for sustainability as something that was not popular when he was a student as he was focusing on nanotechnology but is now an important aspect of the field. This quote indicates that sustainability is important and that change is happening quickly. The professors are aware that the curriculum needs to change with it.

> Dr. Bailey: It's the applications that have changed and I think sustainability is going to be one of them. We really need to face, we really need to sit down and see how we can use 19th Century physics to be applied to modern problems of which sustainability is one and biology is, in my mind, a big component of that because we're killing the planet right?

There is also awareness that change is possible. Professor Harris discussed how engineering education has changed since his undergraduate career in the 1990s.

> Dr. Harris: I think right now, there is a lot of interest in energy. That's different from when I was a student. I was a student in the '90s in mechanical engineering. There was not a lot of interest in energy. In fact, I know I had a couple of professors who used to joke that you know, electrical engineers, nobody talks about the electrical grade anymore. After a while, electrical engineers are not going to know how to power their computers you know? But that's shifted right? I mean there's a lot of focus and effort on the electrical grid and power generation and then it goes across engineering and science. That includes mechanical engineering. I think short term anyway, there's a lot of interest in energy. Longer term though, you already see this a lot and I think that this will be probably the bigger print honestly, is linking engineering to biology.

Individuals contemplating what happens next and how change can be implemented are negotiating this contradiction. This research has demonstrated that this department is actively looking for new ways to impart knowledge of sustainability to students. The department tries things, which sometimes work and sometimes do not. What the department tries is influenced by macro-level needs expressed through hiring organizations, where grant money is given, and jobs that are available to graduates. Also, the what the department offers will have an impact on mid- and macro-level institutions and what skills the new engineers will possess as they become employees. The issue goes back to that primary contradiction of time, specifically, how time will be spent during the education process.

The contradiction of what knowledge should be incorporated into an engineering education was illustrated through the discussion of bio-inspired design. Many participants identified this as an area of growth for the field. The curriculum for engineering mainly consists of math and physics. A subtle change in engineering design that I began to notice in my interviews and participant observations is design influenced by the natural world. Many engineers call this bio-design or design inspired by biology. An example of a project like this that I observed was a senior design project that was a helicopter with a landing mechanism inspired by a bird claw so that it could land on a small strip and grip it like a bird clenches a branch or a wire. This would allow for more diverse landing options for a helicopter. To achieve success in this project the group did extensive study of the way a bird's claw works and closes around an object. This bio-design project resulted in students developing an understanding of birds in a deep way that would not happen to the traditional mechanical engineering student.

This move to design in a way inspired by the natural world is a shift from designs rooted in physics to ones that mimic nature and hence add a new way to use nature to inspire design. To design products inspired by flora and fauna, biology needs to be understood. When asked what the future of mechanical engineering, several professors stated that bio-design would be important. One professor, Dr. Miller put it this way: “Just bio, you know, the bioengineering, biomechanics, robotics, and micro and nano areas are hot.” Professor O’Malley said:

> We all have to have pretty good knowledge of biology across the sciences and engineering. I think that's probably true. I think in the future, that's probably going to be even more true. If you ask where the future goes, I think that biology is just going to be pervasive throughout. Mechanical engineering and engineering in general, I think that may even be the bigger trend longer term than…

Currently, there is no requirement for engineering students to study biology or take classes in the subject. However, professors expressed a need for engineering to have a deeper understanding of biology and to incorporate biology classes into engineering curriculum. One professor noted that with more understanding of biology, students would develop a larger idea of sustainability.

> Dr. Bailey: I've thought for years and told the faculty, but I've given up because they don't listen, but maybe they will now that we have a new group of faculty. Mechanical engineers are not scientifically illiterate because they don't know anything about biology. Biology is just at the basis of so many scientific and important social things these days, including sustainability and ecology that we really should require our students to take and until we require our students to take a biology class, probably something that would be oriented toward the engineer, our students, our graduates, are going to be basically scientifically illiterate.

This adaptation of bioinspired design is a shift in the way that engineers approach the design process. This trend could serve as a nice connection to sustainability. The study of biology could introduce ideas of ecology and increase the connection to things that are alive. Bioinspired design complicates this contradiction. Professor Petrotich described this change in thinking when he said:

> When you think about our curriculum, it's all about inanimate objects. So for attracting students and better educating students and making them scientifically

> literate in the 21st Century, I think it's time to stick some life into mechanical engineering.

It is clear that what is expected of mechanical engineers to know is growing, as this new emphasis on biodesign indicates. Professors are thinking about this, and expanding what students need to learn. Sustainability is a significant issue in this trend.

On a macro-level within the department, faculty are so busy that adding curriculum or teaching in a new way becomes difficult. Dr. Lund spoke to this interplay of micro-time management impacting decisions.

> Thinking about environmental choices also reminds me of the choices I make about how to spend my time at my tenure-track job — ultimately research is more important long-term, but I spend more time on my class. There's an immediate deadline and immediate consequences if I don't prepare well for class v. a longer deadline and less direct consequences if, say, I don't finish this grant proposal.

This nontenured engineering professor describes the dilemma that time management presents to professors. This same professor has an emphasis on sustainability in his research and was hired at Mountain State University for his expertise in sustainability. However, when asked if he fit the topic of sustainability into his class he said:

> Dr. Lund: I have not incorporated it into the assignments, because it is a more qualitative way of thinking and we are trying to cram so much material as it is with energy conversion and I would like to do a better job of that, and require more critical thinking and incorporate more factors, which is hard to do at the undergrad level. I don’t think I have done a very good job of incorporating what I care about and why I am passionate about into the classroom, I would like to do a better job of that. It is so easy day-to-day to get caught up into I have to cover required material.

This required material goes back into the physics that is traditionally associated with thermodynamics. Another professor who eagerly expressed the importance of incorporating sustainability into the curriculum said something similar when asked how he was approaching teaching it in class. Professor Bailey: “I didn't do very much this year. I've been meaning to but just been busy. So we've just, he's got some examples in the text and we talk about when carbon dioxide comes out of a tailpipe or car." They are good representatives of what many of the professors had to say, in that they think the idea of sustainability is important but have trouble fitting it into their classes.

From a student's perspective, they understood that the research was an important part of having a job at a research university, but they did not feel it impacted the teaching. This is a part of a conversation from an industry engineer who did not attend the university, but did go to another research university known for its commitment to sustainability:

> Josh: I think a lot of the problem and maybe this is more because I went to a huge research university, but I think it would be different at a graduate level, but a lot of the professors that I had were specifically at Technical University doing research on something or other. So you could tell they hadn't done a lot of teaching and the courses were just pretty piss poor overall. I think a lot of it came down to just the professors and being their specifically really important research probably that they're working on obviously like the best in their fields with all of their credentials and stuff. I think overall, a lot of them had a huge lack in just understanding or there wasn't an emphasis or an importance to them. I don't know, I think every class should have both aspects brought into it. It's very applicable.

These well-intentioned faculty members are short on time, so they end up allocating their time the best way they can to get done what they have to. This micro-action of not incorporating sustainability into classes because of a lack of time to change curriculum has macro-implications, namely, design processes continue to be done in the same way they always have been done. This is not because people want to do it the same way, but because time constraints make teaching it another way difficult. Currently, teaching about sustainability is seen as something that has to be added onto existing curriculum.

Systems of Tenure, Promotion, and Retention

The next mid-level institutional secondary contradiction to be discussed under the larger contradiction of time occurs in the institution of academia, specifically, between what it takes to provide a quality engineering program and the tenure and promotion process. This contradiction is between what is needed to attain tenure and promotion and the amount of work required to change curriculum in a class. This is a secondary contradiction because two elements exist in a system, but one has to change for the contradiction to get resolved. The two elements in this system are what is required to achieve tenure and what is required to add quality new curriculum to a program. In the current academic system, professors are rewarded for their research, service, and teaching. Creating dynamic new curricula regarding issues such as sustainability is time-consuming and has no benefit to the professor when being reviewed in the tenure process. This system does not indicate that it is an important way to spend time, because it is not rewarded.

> Dr. Harris: Yeah. Well we've talked about how - I think this will relate to sustainability - do we pull it or do we push it? Do we say faculty, you have to teach it because it's going to help you get tenure. Or, do we try to convince the industrial advisory boards, the national advisory boards, to convince the dean to convince the chair that that's what they want to see happen. Then you're pulling sustainability into the curriculum. It's got to be both ways that if the people that the dean listens to, say that sustainability is important.

Currently there is not a reward for bringing sustainability into the curriculum, and thus professors are less likely to make it a priority.

The process to attain tenure at a research university is difficult. Attention must be paid to teaching and service, but highest priority is research and obtaining grants. To achieve tenure assistant professors must make strategic choices about how they spend their time. Some participants mentioned that it was not useful to spend time thinking about how to incorporate sustainability into classes because it would not help them achieve tenure.

> Dr. Harris: I'll tell you, the way in my opinion, any academic department can support anything is to reward it in the form of credit toward our retention, promotion and tenure. By the bottom line is, if it doesn't go on your RPT documentation for retention, for promotion, especially for the younger professors, just talking about it is just a waste of time. Young professors at the assistant professor level that are trying to get promoted to associate in tenure, there's only 24 hours in a day, there's only 7 days in a week and they have to allocate their time to publications, to research and to getting good teaching reviews. Service is nice, but publications, dollars and teaching. If sustainability can be part of that, that's great.

One professor noted that lesson plans around sustainability tend not to help with the tenure process, while another mentioned that it could actually work against you. Professor Petrotich mentioned that if students do not believe in climate change or disagree with the subject, they can produce terrible student evaluations that will count against the professor when going up for tenure:

> I mean we don't get a reward from student evaluations by talking about it. Not really, in fact you kind of go out a little bit on a limb, it's not an equation, students think it is like an opinion. They haven't had the training and they haven't learned about it in a way that they can talk about it, communicate it in a way that they feel comfortable. I'm unusual in that I have started buttons in ethics and I've taught both courses and I'm taking courses in environmental ethics so I understand conflict.

Because tenure is a goal that most professors have, if teaching sustainability is not rewarded they are not going to spend the resource of time in pursuing it.

The tenure process is important to professors. Without achieving tenure, faculty lose their jobs. Because of this, the contradiction of teaching sustainability while balancing the tenure process is not easily negotiated. With time as a limited resource, the professors choose to spend energy on endeavors that will help them attain tenure. Currently, this becomes an either/or proposition. Professors must either spend time in an activity that will help them to receive tenure or not. This system of tenure is deeply situated in an academic tradition that is not unique to this department. Hence the tenure process is impacted by larger structures of tenure set up throughout academia. Mountain State University would be hard pressed to reinvent the tenure process; it is too bound to the larger idea of academia. The value of pursuits such as grants or publications is determined by a constellation of universities, engineering programs, and Mountain State University. This idea of what is valued (incorporating sustainability into classes) is not left to the professor or the department alone.

Time and the contradictions surrounding the concept of time became a major theme of this project. Overarching, the contradiction between the timeline of climate change and that of the university schedule expresses a challenge that embodies the challenge between natures schedule and the schedule of organizations. Moving to the mid-level contradictions, these are challenges of time that exist within organizations. The challenge of fitting all the knowledge necessary to accommodate ABET and the needs that future engineers into an already bursting academic schedule creates a difficult challenge for a program already having difficulty in getting all materials covered. Most often these contradictions are negotiated by actors reverting to actions that reflect the status quo. Classes continue to be taught as they have been in the past, even in the face of a changing world. Overextended professors and students continue doing the best they can. However, new exploration of subjects such as sustainability go to the wayside. Not enough time is a commonality between these mid- and macro-level contradictions: Not enough time to stop climate change, not enough time to learn everything necessary to be an engineer, and not enough time for faculty to accomplish everything they need to. These contradictions and pressure are tied together at the micro-, mid-, and macro-levels of society. Now that the macro-contradiction of time has been discussed, the next topic will be economic structures.

Economics as Priority and Economics as Social Responsibility

The next contradiction revolves around economic structures. This is a secondary contradiction, constructed between two societal structures. Secondary contradictions appear between two elements in a structure in which one element will have to change for the contradiction to be resolved. In this contradiction, the two elements are a perceived oppositional tension between economic rewards and that which is the collective good for humanity. Many participants expressed the idea that economic success came at the expense of social good. Most engineers talked about how the bottom line was the most important consideration, but some professors have created lesson plans that will expand ways of thinking about market systems. Many engineers I spoke to, particularly the practicing ones, talked about how long-term savings or a more sustainable product was often overlooked because of the initial expense. This is another example of a secondary contradiction. In the current economic system, the initial profit or bottom line is the most important thing. Long-term thinking that would incorporate concepts from the triple bottom line is not part of the current way of considering profitability. This example from Bob, a man who owns his own mechanical engineering firm, exemplifies popular thinking about how design fits in to the current economic system:

> Bob: In terms of that, I'm sure that the universities are now focusing in great detail on the new developments and lighting designs with LED light sources in addition to the fluorescents and the really efficient fluorescents was a really big deal and now it's LED. LED is beginning to penetrate the Mountain market because the costs have come down. It was as recently as two and a half years ago on a project we were recommending against it on an industrial project just because it was really expensive. We were doing a type of lighting that was only

> going to involve light lamp replacement like every five years, but the maintenance people had heard about the LED fixtures. "You don't ever have to replace the lamp, so we'd love to have them" you know. And we were like that's not really the economic choice at the moment. I'd have to investigate it again right now to decide how I was going to answer that question today. But it's changing rapidly because the prevalence of LED light sources is expanding and the quality is not just, there's a lot more that goes into whether an LED source is appropriate than just this source versus that source. It's how it's implemented and how it actually emits light from the fixture that it's in. Whether it's doing the job that you need it to do. There's market forces still in play that are keeping things from moving in that direction just because, I mean, it has to be are the people that are doing that, are they just oblivious to all the discussion or are they just totally not willing to commit the funding to it to try to be more responsible if you want to call it that way. We try to routinely specify one or two steps above on the rooftop equipment, about the efficiency on the cooling side. On the heating side, you can't do anything about it, it's still not available. But on the cooling side you know, inevitably there's projects where the guy that's building it says "Well that's too much. What can you do to save me some money?"

Another practicing engineer, Josh, reinforced this idea:

> Josh: It was fascinating to me when I was working at Company X and we were working on utility and we were trying to give away money to people supporting higher efficiency equipment and you can buy something like all the payment periods are three to five years and it was so hard to give away free money. You want to get a huge organization like The Church, they wouldn't implement any stuff into their buildings if the payback was longer than seven years.

This idea of considering an economic system in terms of how much the design will cost at the point of creation is a current and popular way to look at the value of a design. Because of that, sustainable design is often not as attractive because it is seen as more expensive. An engineering student pointed out that until the way that costs are calculated is changed to a more long-term way of looking at things, engineers will continue to design with the short-term costs in mind.

> Luke: Maybe to a degree you can design things a little smarter, but I also think there's also a whole social aspect of this that it's not just an engineering problem. I think it really is a social problem that has to be attacked on a social level to a degree because it's, like I said, you have to build a product, but people have to be willing to pay to absorb the cost of the cradle to grave somewhere. If you're, as an engineer, you're worried about that as an engineer from the beginning and you have a product that costs so much people won't buy it, there's still a problem

> there. I don't see it just as an engineering problem, I see it also as a social problem.

The current economic system is limited and does not account for externalities, which opens the economic system to look at costs not currently considered or social costs such as environmental cleanup or public health. This is a macro-structure that impacts what mid-level institutions find important and how engineers decide to design a project. This is being negotiated within the department by professors emphasizing different aspects of economies when they teach. Currently professors who teach about sustainability say they have the most success using the concepts of economic systems to reach students, looking at long-term cost-benefit or externalities to help students understand the greater systems involved than simply making a profit. The professor in charge of the LEAP program described his tactic at teaching the cost as follows:

> Dr. Tolliaferro: Yeah, that's sort of another avenue that I try to push and that comes from the economics of it is sort of the costs and benefits and how to really - you know, you may be designing the bridge and you're going to receive some benefits from driving across that bridge and shortening that gap, but what are the costs? And the costs can be incorporated in a bunch of different ways.
>
> Maria: That's part of sustainability, right? Is the economic impact?
>
> Dr. Tolliaferro: Well yeah, I think that's a large part of it. It brings in the systems idyllic. Everything you've designed is part of the entire system, which is why you're responsible for it. You're not operating a vacuum.

More emphatically, professor Petrotich described the way he teaches about externalities and the free market to students:

> Dr. Petrotich: Working with those people and trying to get their message out there in a way that resonates with their audience and making sure that that's working. Always going back to this idea that externality can save them. I think that is the, I really do think that is the solution. See here's the economic construct is that we've got an economic system that ends up doing really very well because we take this abstract thing called money, and then we assign an abstract value to labor and to energy and materials. Then we want to make this product, so I want to make the most out of abstract money you know, profit. So

> what do I do? I try to figure out how to get this made minimizing labor, minimizing the amount of energy, minimizing the amount of materials that I put into it. That's the way our free market system has worked and why it works so well and beats communism. See because we've got this built in optimization piece that goes around the idea of obtaining a profit. But those are not the costs. The other cost is the national capital that's being used and was never figured out to that calculation. If that were charged at value, then were going to the right direction because we're giving it away. As long as we're giving it away, that capital is being taken as much as it possibly can. There is no downside to doing it. So this idea that you put those, you make them pay for those externalities and once you do that you'll be like "oh, we're not going to do that anymore". I'm going to take a different pathway to the externalities because it's cheaper. And it really is cheaper. Whereas this consideration of externalities is really a big part of it.

Utilizing different concepts of economic systems to open the students up to consider the true cost of design is an example of a place where a contradiction is being negotiated to teach sustainability to students. Expanding thinking about resources to include more than an instant profit, to think about the health of people, the ecosystem, and the atmosphere, would change the way that the cost of sustainable design is perceived. And this seems to be working: Some students identified sustainability as long-lasting products and were able to define the triple bottom line. These are indications that the socialization process has incorporated sustainability as it is related to cost. Some professors have changed their approach by creating a new set of knowledge resources for students to draw upon when thinking about design. Teaching individuals to think about economics in this way connects larger systems to individuals.

Thinking and teaching about social and economic systems in a different way allows for a reconfiguration of resources. This new way considers the interaction between humans and natural systems. This use of alternative ways of thinking can help some engineers manage the secondary contradiction of economic profit being in conflict with sustainable design.

New Responsibilities of Being a Professor Replacing the Traditional Job Expectation

Macro-level economic structures set the stage for issues of funding and money in mid-level institutions. Although the traditional role of the academic was research and teaching, a new entity, finding funding for the department has become and important part of the job description of professor. Funding is a tertiary contradiction found at the mid-level institutional level dealing with the macro-issue of economics. Tertiary contradictions come about when a new entity, more advanced, is introduced into an activity. The new entity in this case is the need to be awarded grants. The only way to elevate this contradiction is a change in practice or systems. Funding is a resource that is important to academic institutions. The way that departments acquire funding has undergone some major changes in the last 30 years (Mortenson, 2012). In the past, state-run institutions were allocated money through the legislature, and departments would be funded through the school. Now, most legislatures allocate significantly less money to schools, and individual professors are responsible for procuring outside funding and grants.

Giddens (1984) emphasizes the importance of rules and resources in creating systems, and repeatedly funding and money were identified as an important resource. Participants mentioned that if more funding were granted to sustainable design, then engineers would be more inclined to consider it in the design process. Money and funding has a large impact on how classes are designed, projects are chosen, research is conducted, and careers are planned. Many of the participants stated that they would design any way they were being paid to design. Professors mentioned that if designing in a more sustainable way helped them get more funding through grants they would adopt that method with more enthusiasm.

To clarify, the National Science Foundation often supports grants that encourage sustainability. However, it is not a required design factor for every grant. For example, a mechanical engineer who focuses research on robotics does not currently have to consider the environmental impacts of their design or how sustainable the project is in the grant application. It is not an intrinsic part of the application process. There are grants in which sustainability is the focus, but because of that, those who do sustainably designed research are designated a "sustainability researcher" and perform within that specialization. Hence sustainability becomes a compartmentalized specialty instead of a thread that spans the entire field.

Professors are required to search out funding for their research agendas, and currently sustainable design is not being rewarded to all mechanical engineers. Because of that, many participants indicated that if the system were set up in a way to advocate for sustainable design, especially through the resources of money to support research, the actor would behave in a different manner.

> Dr. Lewis: Yes it is, because there's not a lot of funding for - you know there's funding for the phenomena that you might be studying that could be applied to improve efficiency or energy usage. Okay, so it's somewhat related to sustainability but it's not on a global scale where most of us think of sustainability.
>
> Maria: Yeah.
>
> Dr. Lewis: Energy usage, energy conservation and things like that. There's still not a lot of funding for that kind of work research wise. So we're not finding these trained people. If there's more funding, then that would attract more people that do that kind of work.
>
> Maria: Right.

> Dr. Lewis: Which would bring in more graduate students which would provide a trained group of future professors and people for the workforce. We're all kind of driven by funding, I mean that's what we have to do.
>
> Dr. Lewis: A lot of it's tied to Washington.
>
> Maria: Yeah.
>
> Dr. Lewis: This is a national issue.
>
> Maria: Absolutely.
>
> Dr. Lewis: If they invest more through the Department of Energy through the National Science Foundation, through other organizations, they're going to attract research. That's going to lead to all these things that we've talked about.

He later expressed that it was a tough situation in which professors had to get funding to run their labs; however, governmental funding and grants were becoming less available.

> Dr. Lewis: That's got to come from - in this country, the way the system works, someone's got to be willing to invest in it. Corporations have to be economically inclined to take a look at alternatives. Let's say you're in the oil business. Should you be thinking about solar and wind? Because if you're a large corporation and oil is getting harder and harder to find, perhaps you should invest in your future of the company by maybe looking at these alternatives now. I don't know how many are doing that? Likewise, if the government feels this is a problem for the country's future, then they need to invest in it now. One way you invest is through these national agencies; Department of Energy being the first one obviously. But they have to tailor their requests for proposals for research around what they believe are the major problems that will attract interest and like I said, that's where so many other things and so many other changes - but as you know, money is tight in Washington. Research budgets are being cut. This country, we need to make some tough decisions and you know a large part of our tax dollars goes to the military, goes to other places which really isn't thinking about our future as much. That's very political obviously.

Currently academics have to attain funding for research and jobs to be employed in academia. The structure of the institution and how it distributes money has shifted, and professors have to change behavior to be rewarded within the system. Embedded within this new job description is the examination of what ideas and research gets rewarded through funding. Presently, infusing sustainability into every mechanical engineering project that is funded is not a priority. Josh pointed out that if sustainable design and decreasing global climate change were a priority to the government, it would happen in a large-scale funding action from the U.S. government.

> Josh: So you can't fix a lot of these problems because we don't have quite, I guess we could make more money, we're doing it all the time, but I think without like a huge core push or project somewhere to just like NASA and the space program, with the Cold War and stuff, or the Depression and looking at the CCC and all the stuff they did with building projects like the dams and the roads and the trails and all the planting the trees and everything all over the country. We need something along that scale. A JFK-type in implementation of this sustainability stuff like training in tech school and implementation in engineering programs and incentives for companies and looking at something like the Great Depression or the Cold War and climate change being in that same sort of category of a worthy adversary that we need to take seriously and push against it and try to accomplish or have a concrete objective or goal.

The foundation of this tertiary contradiction is that professors don't have to be just good thinkers and educators, they also have to be great moneymakers. The goal being sought is funding for academic research and teaching endeavors, so they can stay active within the system. The nature of higher education has changed the orientation of activities.

Much of the work that is done in the department is funded through grants from the Department of Energy or the National Science Foundation. The call for grants that these organizations send out has a great deal to do with the sort of research and work that professors are engaging in. The macro-level has an impact on how professors decided to conduct research. A professor who teaches in the LEAP program observed the grant process as follows:

> Dr. Tolliaferro: Really, the way engineering functions with research is, it's very grant driven. Those grants are usually investment based so people want to see an actionable technology come out of the end of five years. What that ends up doing oftentimes is there is a lot of research in sustainability which is 20 years

> from being able to be sold. But it's really important research that needs to be done. So oftentimes those grants are much more difficult to get. What happens is new admit PhDs need some money for their labs so they're going to go more toward some sort of marketable technology and then the money flows more into computers and electrical engineering because that's where you can make money quickly. So if there's anything the engineering department can do would be to really, as an undergraduate, is to really foster the idea of research for its own sake. Research that might not be sellable but is important. That, I think, is a hard thing to do and you even have engineers, we have usually a few professors come in and talk in class. I know a few of them that are really interesting and I try to bring those guys in who are interested in their research and their research's you know - one case, probably 50 years out from being…From being actionable. But it's great stuff and it really has to do with designing computer chips to work with light. But then other ones come in and they're like, they rattle off in the beginning of class how many patents they have, how much money you can make in these different engineering degrees and here's the things that I've designed… Then the thing is they latch onto that because that's what they can understand. You see the dollar signs of money and you're like "oh, I'm going to do that". You'd be upsetting the whole entire university system to start manipulating that. But I think that's one of the areas where the engineering program could really work more toward research for research sake; more like the College of Science does.

The money that is available to professors to fund research often needs to be able to produce results that will produce more resources. Dr. Lewis observed that the grant money can come from the government or from corporations, but wherever it comes from, macro-level institutions determine the money that trickles into universities.

> Dr. Lewis: That's got to come from - in this country, the way the system works, someone's got to be willing to invest in it. Corporations have to be economically inclined to take a look at alternatives. Let's say you're in the oil business. Should you be thinking about solar and wind? Because if you're a large corporation and oil is getting harder and harder to find, perhaps you should invest in your future of the company by maybe looking at these alternatives now. I don't know how many are doing that. Likewise, if the government feels this is a problem for the country's future, then they need to invest in it now. One way you invest is through these national agencies; Department of Energy being the first one obviously. But they have to tailor their requests for proposals for research around what they believe are the major problems. That will attract interest and like I said, that's where so many other things and so many other changes - but as you know, money is tight in Washington. Research budgets are being cut. This country, we need to make some tough decisions and you know a large part of our tax dollars goes to the military, goes to other places which really isn't thinking about our future as much. That's very political obviously.

The money provided for grants is an important resource to these engineers and the labs they run and the research they do. One professor explicitly stated that the only way that sustainability would be incorporated into classes would be through writing a grant, because resources are so limited. This expresses a commitment to a particular way of doing things that is inflexible. This mid-level contradiction has a major impact on the way that individuals in this organization choose to spend time; the interplay between the mid-level and the organizational level is great within this contradiction.

> Dr. Bailey: If people would write grants, agree, if faculty would have a meeting and agree we would need to infuse sustainability issues throughout the curriculum like this spiral thing. Then that would require TAs and it would require developing modules and it would require maybe developing some new laboratories and making sure they were put into the curriculum and distributed throughout the curriculum and so that would take resources; so getting resources and allocating resources. Resources are tough. Our enrollments have shot up as you know, so as you've seen, so we're really strapped as a department. Getting more resources to do these things would be what the department could do.

Grants provide resources for additional research and classes at the university. The access to grants represents a macro-influence on an individual, what they can apply for and how they spend their time. Nevertheless, what is popular to be funded does not stay consistent and is impacted by trends. One professor spoke about this ebb and flow of funding and how difficult it can be if what you want to study is not *en vogue*.

> Dr. Ebert : I'm sure there's challenges as always there's kind of phases that things come and go and there's an ebb and flow in science where we see funding cycles where topics become popular and then that popularity fades and they come back and we've seen that over and over again. We're just repeating a lot of that work at the nano and macro-levels that were more macro 20, 30 years ago. We're just going through that same process with a different scale but a lot of it's similar. So funding can be challenging. What people, what the government essentially is interested in funding, that seems to be what drives research and outcomes.
>
> Grants have become a resource for the department. Faculty who specialize in

sustainability have received grants, and the 1000- and 2000-level spiral was funded through grants. Sustainability is a topic that can be rewarded with money. With that said, those who do not specialize in it do not have to address the subject in their grants. As graduate students, mechanical engineers pick a specialty to study ranging from nanotechnology to robotics to thermodynamics to sustainability. Calls for grants are written specifically for a particular branch of mechanical engineering. Although there are some grants designed for engineers with sustainability as a focus, sustainability does not have to be addressed in all grants.

Professors stated that their awareness of sustainability and the incorporation of it in their work would be more prevalent if every grant had to address aspects of sustainability in the proposal. If there were a change at the structural level such that every grant application that went to the National Science Foundation had to address things like cradle-to-cradle design and emissions output of the design, then ideas of sustainability would permeate more of the field than just those that specialize in sustainability.

Money is a resource that many of the participants said had a large impact on how they navigated the issue of incorporating sustainability. First because professors said that if grant money were made available to support research efforts in sustainability, then they would more ambitiously pursue that line of research. Students also expressed that if they felt there would be financial rewards or career advantages they would become more interested in sustainability. Funding and making a good living after graduating are important topics to the participants with whom I spoke. Money becomes a reward, something worth striving for.

The Compartmentalization of Sustainability by Making it a Specialization

Regarding sustainability, the presence of a few specialists in the department means that everyone does not feel they have to teach the subject. There are a few specialists in the department who serve as resources for teaching and learning sustainability. Because a few faculty members are appointed the "people who do sustainability," the expertise in the department is compartmentalized. This creates a primary contradiction within the department. A primary contradiction is when two oppositional tensions exist within the same activity systems. There is a desire to emphasize sustainability within the department so specialists are hired. However, the specialists bear the burden of teaching all of sustainability so that other faculty members are "off the hook" thus making sustainability less of a priority overall. Sustainability is left to the experts because of this, so it is not incorporated into all classes and research. Instead it is assigned to the dedicated few. As discussed in research question 1 there are some exciting things happening in this department in sustainability education. The department has made decisions to hire faculty with a concentration in sustainability. There are several electives offered to teach more about the subject, and every year there are a few senior design projects that focus on sustainable design. These experts get turned to in regard to everything sustainability related.

Almost every person whom I contacted to interview stated that I needed to talk to the few specific professors who specialize in sustainability. Three individuals declined an interview, stating that they would have nothing to talk about and instead gave me a list of the professors I should talk to instead of them. The following conversation is a good example of what happened at some point in almost every interview. I would be asking the person about their ideas and beliefs on sustainability and they would turn the conversation to the professors they think I should talk to.

> Maria: It's been great. So I have a few more like that have sustainability as part of their thing that I'm still…
>
> Dr. Tayler: So have you heard back from Bajpai?
>
> Maria: Not yet.
>
> Dr. Tayler: Okay. And how about Dr. Petrotich?
>
> Maria: Neither of those. So I'm going to send some follow-up emails…
>
> Dr. Tayler: Good. Dr. Petrotich, I don't know where he is. He's been on sabbatical.
>
> Dr. Tayler: But yeah, they are the two I would think. And how about Dr. Bailey, Did he reply?
>
> Dr. Tayler: We just hired somebody new. Dr. Lund.
>
> Maria: Yeah.
>
> Dr. Tayler: Have you connected with her?
>
> Maria: I have not.
>
> Dr. Tayler: You should…
>
> Maria: Every person has brought her up.
>
> Dr. Tayler: Because she, okay. There you go. That's all I can think of.

These recommendations of individuals to talk to was a reflection of how helpful people in this department were in my research, and I feel that the intent was to be accommodating. It is also indicative of a department that points to a few experts such that individuals do not have to consider sustainability because there are others who take responsibility. The following quote is a professor outlining which individuals in the department can be depended on to teach sustainability:

> Well I think that's evolving. We have now Petrotich who's, you're probably trying to get hold of, that's more his background. Bagpai is a manufacturing guy whose interest ties in with that. So I would have to say the fact that Petrotich is here and is a major part of the department indicates that we attach some value to it because we have one FTE, one faculty slot that is assigned to that. There is one or two courses now, I think, I'm sure if there is two or just one that Petrotich and Bagpai have taught, which you probably have seen. Any time a course is taught by definition, there's a value associated with that topic because department resources…

The next quote specifically outlines the people committed to sustainability, but also acknowledges that these are fragments in the curriculum and not part of an overall mission to bring sustainability education to the students.

> Dr. Harris: We have just hired a person, a person in the thermo sciences area and we have people in the fluid dynamics area that have like Robert Donaldson and Peter Metz and Rebecca that do a lot of environmentally related things. Will Nickel does composites, which are a big point. A big part of saving energies through lightweight structures, improved structures. So there are these little separated currents that run through things and we've got Dr. Petrotich we hired because of his sustainability expertise. So there are lots of little pieces going on. So the department has made this sort of implicit commitment to it. But in terms of the curriculum and teaching our students, because some of those people's research are in those areas. But in terms of sitting down and saying we need to revise the curriculum in order to make our students scientifically literate in the 21st Century, no we've not done that.

This professor is one of many who mentioned the new hire who has a focus in sustainability. It is exciting as a department to have a new hire, and the fact that their research is focused on sustainability made their arrival an important part of information to this research.

> Dr. Lewis: …think we're going to do more of that (electives in sustainability) because we've just hired a new person whose research is on sort of global energy use, sort of building level, urban environment level…And they are very nontraditional in the sense of most engineers and will probably do a lot of work with architecture and urban planning and things like that. So that's a specific decision we've made to invest in personnel who are going to conduct research which means our graduate students will go and do research in that area. So we are making an investment and conscious decision to get more involved I guess.

> Dr. Richards: There's maybe things might change in a few months in the

> department because we just hired a new professor with the field of expertise in sustainability.

Dr. Petrotich is so affiliated with sustainability that he was mentioned in almost every interview and is dubbed “Mr. Sustainability.”

> Dr. Taylor: Have you communicated with Petrotich?
>
> Maria: You know, I have sent the email that I have sent everyone, but I really look forward to talking to him. I've heard so much about his lab.
>
> Dr. Taylor: Okay. Yeah because he's really the sustainability guy but it's just something I'm thinking about him is he's really, he has strong opinions right?
>
> Maria: Yeah.
>
> Dr. Taylor: He's Mr. Sustainability and he has a strong opinion. I had a student coming in my office saying "this class is fun, but I disagree with the professor.” I hate that.

One student named Sam described his most in-depth education in sustainability as coming from Professor Petrotich: “I believe Petrotich does a pretty good job of conveying to his students why sustainable energy systems are important.” Another student named John, when asked about learning about sustainability, said, “Petrotich. So he'll talk about the difficulties and how a lot of things that people are trying may not work currently, may have negative effects. He's just good at being scientific while holding his strong beliefs and support of the underlying values.” Allen, a senior, described Dr. Petrotich like this:

> Dr. Petrotich, I think he should be a hero. He should be a poster boy as far as that's concerned. Sustainable design is like his focus and specialty. His major goal is to try to not get something out of nothing, but try to take what is and harness it for the most we can and leave as little a mess as possible. I think that's down the line. I mean it's inspiring for one thing, especially for somebody in his position. He's got a great influence on all of us, bolstered by the fact that he's a really cool guy in addition. I've seen it and I'm for it. I enjoy it.

These sustainability-focused researchers become a large part of how the department conceptualizes how they are teaching sustainability. When they have one or two people who do it, then the whole department is doing it.

> Dr. Harris: Yeah, by Petrotich who is a sustainability guy. It's important for us in fact, I think we just hired a new faculty member who is going to join the department in the fall and their focus is sustainability. Yeah, I guess that's my perception that it's important to our department.

This is a great resource for the department, having extremely talented researchers and professors who think deeply about sustainable design. Their presence in the department demonstrates that sustainability is important. It should also be noted that allocating salary funds for several "sustainability" professors is a large commitment. With that said, it can be problematic to have certain individuals who have been given the responsibility of being the ones "handling" sustainability in the department, especially since those individuals do not feel that they are able to accomplish what needs to be done on their own. One graduate advisor from the department noticed that one professor who specialized in sustainability had the burden of advising every student who was interested in the subject.

> Abi: I think they're trying to enhance sustainability within that thermo-fluids area and to try to make it a little bit more of a stronger area to kind of draw the students who are interested in researching that and also don't overwhelm Petrotich so he doesn't have 20 grad students who want to study with him and do sustainability. Sort of spread that out. But I don't feel like, when I was there, there weren't many talks about pulling that across to the other three areas. It was sort of like contained in this little box and then either it was something that students were interested in and they would do it or they weren't and it wasn't necessarily integral.

This contradiction is the demonstration of valuing the idea of sustainable design by hiring specialists in this field, but not valuing it enough to have every faculty member be able to some level of competency in the area. Having specialized sustainability people who concentrate on the topic relieves others from having to focus on it. This creates a contradiction whereby the faculty who are not focused on sustainability do not feel a need to integrate it into their teaching or research. Weick and Sutcliffe (2007) warn against creating organizational silos because it is difficult to get a holistic view of what is happening within the organization when there are divisions.

This specialization is having an impact at Mountain State University. However it is a reflection of the impacts of specialization at a mid- and macro-levels of the system. Because sustainability is not a subject integrated into the course of study at all engineering schools, those teaching at Mountain State University were not socialized for it to be part of the expected knowledge of all engineers. Because it is a specialization at the macro-level it is a specialization at the macro-level.

This creates a large responsibility for the sustainability-focused faculty. These individuals do not feel that they have the topic covered. The new faculty member hired specifically for their expertise in sustainability expressed the feeling that they had not had time to figure out how to incorporate sustainability into the classes they were teaching. The established "sustainability guy," when asked what it is like to be the point person on this topic said:

> Dr. Petrotich: I don't have it covered at all. No. I don't think we have it covered at all. We're going to be looking at a big transition and our students need to understand what they're going to be looking at. And they need to understand the dynamics of what's been happening over time. It's not a static situation. Whatever you throw out there today is going to change tomorrow. We need to stay with the fundamentals always in teaching. When you look at something that you know is going to change so much, you get back to the fundamentals. I think one of the fundamentals, especially when you're looking at change, that has the potential to cause so much human suffering, I think you have to address it. That's what we do as engineers; we try to make the world better. What is it we can make better? That's it. So what should we be doing?
>
> Maria: Yeah.
>
> Dr. Petrotich: That's what we should be doing. But I'm not hearing that. I'm

> not hearing that. In fact, I'm kind of a lone wolf sometimes talking about it. It doesn't help me along and I'm told it makes a lot of people grumpy. [laughter] But I keep doing it because again, I think it's important because again, I'm a university professor. I understand what's going on. I can fit pretty clearly and I understand what engineers can do to make it better. It's my job to talk about it. It's my job. Also, within my code of ethics, it's very clear that if I have an expertise and in there is pertinent to the public's need for that information, I really have an obligation to do something about it. One of the few people that will write commentaries and get out there and put information out there to the public so that they can start understanding the context. Again, engineers have kind of a special role in that in a way because we can interpret things in a way that people need to figure out. So again, that's part of the responsibility that I take very seriously as well. But I'm very rare. I guess very rare is redundant, isn't it? But rare within the college. I don't know many people that are quite where I am on the understanding. I think part of it is I have two young daughters, a 9-year-old and a 7-year-old, and I look at their lifetimes and think this could get really bad and it scares me. I don't want to think of horrible things that will happen, especially if I knew that I could have done something to fix it. Engineers are optimists.

When sustainability is relegated to a few people with a very particular specialization, the organization can compartmentalize sustainability in one particular part of the organization and not have to create a holistic strategy to integrate this different kind of thinking for all students. If students never take a class or choose an elective from one of the designated sustainability teachers, they can get through their entire education without coming into contact with these ideas. Because individuals choose electives, only a self-selecting group of students will be exposed to this sustainability education which has an impact on how students are being socialized.

This creates a division between those who focus on sustainability and those who do not. Most of the professors I spoke to were not opposed to teaching sustainability. In fact many thought it was important to address the subject more thoroughly. Again, this is a resource because most faculty members were supportive and saw the importance of sustainability being incorporated into the program. For example, Professor Tayler said, “Not that we don't think it should be done, just we're not doing it ourselves.” Many professors were not opposed to sustainability; they just were not doing it themselves.

This is not to say that everyone in the department found sustainability education to be of value to the students in their engineering program. A few professors expressed that sustainability was not relevant or important to their classes. In a few of the interviews professors expressed that they felt that sustainability was a fad and not foundationally important for new engineers to learn. The following is a conversation with Dr. O'Malley who expressed a lack of interest in including sustainability because he did not buy into the concept:

> Maria: With limited class time, how do you prioritize the different aspects of things you need to get into your class? Of science, math, design process and any sustainability or environmental?
>
> Dr. O'Malley: I don't include anything about sustainability. I don't even think I have ever mentioned that word in class. I think it's a hype word. So how do I prioritize? I have my syllabus and I try to follow my syllabus and I stick to the plan what I've prepared. But there is not really any need for prioritizing because I just follow my entire lecture plan and give all the information to the students.
>
> Maria: Just to follow up on sustainability being a "hype" word, would you like to say anything more about that? Why do you think that?
>
> Dr. O'Malley: It just seems like everything has an aspect of sustainability involved in it and I don't see how that's relevant to the classes that I'm teaching.
>
> Maria: Okay.
>
> Dr. O'Malley: I don't think I need to mention it. I teach basic science or applied science, methodologies and calculation methods that are purely based on math and physics, but math and physics have no relationship to sustainability. That's not relevant to my classes. In my class I teach calculation methods and basic science underlying design of mechanical elements. But that's not necessarily related to sustainable designing. Sustainable design is more related to product development, which is something I don't do. I teach basic science or applied science, methodologies and calculation methods that are purely based on math and physics, but math and physics have no relationship to sustainability.

Some were not as opposed to the concept of sustainability, but did not think it was an important part of the curriculum. They feel that the basics of science, physics, and design are what need to be taught.

> Dr. Lewis: I think it's mainly just - my feeling is - that they have a strong foundation in the subject matter that we deliver so that they can apply it to these critical problems for humanity which are sustainability related. I don't think we need to be doing that much personally on sustainable problems. Yeah, we need to do some because it's of interest and we want to keep their interest and some of them are very topical, but I don't think we need to teach a lot of coursework in sustainability. In order from a mechanical engineering perspective, to work on these problems you have to have solid foundations in fluid mechanics, heat transfer mathematics, etcetera, etcetera, etcetera. If you don't have that, you're not going to be able to contribute very well in the arena. We still are focused on the fundamentals, but also trying to recognize and indicate to the students that they can apply these tools that they are learning to these big problems.

Others felt that by covering the fundamentals they would have the skills to apply those concepts to any subject, including sustainability. Or that sustainability does not have to be explicitly talked about because those concepts are implicit in the design process. This is a way of dealing with the contradiction by ignoring it. These professors felt that the math and science is what needs to be learned:

> Dr. Richards: When you see a system of something, try to understand the physics, try to assume what is going on. Then the mathematical description should follow in a straightforward manner when you understand the physics. So that's the way I approach my classes. Really understanding the physics, then the technical side. As far as design and sustainability is concerned, it's more or less addressed in the class I'm teaching.

> Dr. Foster: I probably try to focus on things that are more foundational. If I'm going to prioritize things, I'm going to prioritize things that are more foundational which they can apply across a broader spectrum of situations in which they find themselves. Things that are more application oriented, while we would like to get into those to drive interest and so forth, engineers in particular I think tend to be pragmatically minded. So it's really important to see the change from a particular application down to foundational elements. That's important. But in terms of teaching, I'm going to focus on the foundational elements, because especially as an undergraduate, there's a lot of that to learn and they need that base, they need that foundation.

> Dr. Powell: Well, I think there are a lot of classes in mechanical engineering that correspond very well to those issues. When you face a design question, what material am I going to use, etcetera? Am I going to tie in this so it's recyclable? All kinds of stuff. Dynamics is just the study of how things move under force.

> So you apply force, it accelerates. We don't do any design to speak of in dynamics, so it's really understanding how the world works. So it's difficult for me to find any environmental or sustainability type applications.
>
> Maria: That's super reasonable. This may seem again redundant, but any of the other; economic, social, do those fit in at all? Do you not have to worry about those?
>
> Dr. Powell: I would say that neither one actually plays a role in just teaching principles of mechanics.

Students did not implicitly understand, however, that the skills they were learning were related to sustainability, as indicated by this student, Sam.

> Sam: Okay. Like I talked about earlier, I do think if they want us to have more depth in sustainability, and I don't exactly know what the whole scope is and the upper education community amongst the nation, but if they would like us to have more depth in that, it will have to be taught a little better. They do brush upon it and with the time they have, they do a good job. But if they want us to know a lot more about it, they're going to have to give us more time.

The macro-contradictions found within the economic system manifests in the world of academia. Acquiring funding becomes a priority for professors instead of designing classes, research, or being able to create a holistic curriculum. As you often hear, time is money. The macro-contradictions of time and economy share the commonality that there is too little of each of them. I have described how these contradictions interact with each other. However, a visual representation of the interplay between contradictions and the levels in which they occur can be useful. Figure 1 provides such a visual illustration.

Professional Expectations Contradicting Internal Concepts of Self

Most of the contradictions that I identified can be classified as either time or economy. However, throughout this study contradictions of identity were identified. Most of these contradictions were found at the macro-level because individuals were speaking of their personal experiences. However, these reflect expectations of the idea of the engineer at a mid- and macro-level.

Contradictions regarding identity are a common theme that emerged in interviews. In this contradiction participants are trying to work out their identities within themselves as organizational members. There is a tension between who they think they should be to be a good organizational member and personal identities. It is a primary contradiction, or a tension within one single element. This contradiction within the element is what a person can be (ideology, behavior, looks, beliefs) and be a good organizational member when those two things appear to be at odds with each other. For example, can a member be both an environmentalist and a good engineer? Hogg and Terry (2000) outline that people develop a sense of self and identity from the organization to which they belong. Self-conceptualization is impacted by the values and culture of the workplace. As discussed earlier, part of the socialization process is this adoption of the workplace identity by the organizational member. As one becomes a part of an organization there is a negotiation as one adopts the ways of thinking like the rest of the group. This process is socialization.

The next section will address the ways in which conflicting ideas about identity as organizational members create contradictions. The first identity is that of the political nature of engineering, the second is the role of masculinity in the identity of engineering, and third is the idea of not wanting to be seen as counter-culture. There are norms in this department about what typical organizational members are like. In this organization there were data to indicate the norm is to be nonpolitical, masculine, and not a “hippy.” However, some members indicated that they had internal signals that went against the norms of the organization. Here I describe this contradiction and how it is managed. I introduce the concepts of "cloistered advocates" as an important and previously overlooked role in organizational change.

The Identity of the Engineer as a Nonpolitical Being

The political nature of engineering is a primary contradiction because many engineering students and professors explain that they are uninterested in jobs of a political nature and that they are drawn to engineering because it is based on foundations of math and physics. Their socialization process leads them to understand themselves as nonpolitical entities. However, due to environmental regulations, laws, and funding the larger systems of government and politics end up being an aspect of engineering that is part of the business of being an engineer.

Many participants mentioned the lack of discussion of political or social issues in engineering classes. Professors are wary of teaching controversial topics or veering away from discussions that are not centered in Newtonian thought. Students discussed this in interviews as they described engineering classes and how subjects of environmentalism and sustainability were presented in class. One student talked about how engineering classes were more empirically based:

> Sam: That's another topic that's kind of brushed upon. The big thing in engineering is we're under such time crunch that political discussion and emotionally driven discussion rarely happens. The one thing I've noticed in taking general education classes, a lot of political influence makes their way into the classes. That just does not happen in engineering. It is cut, dry, here's an equation, here's how you use it, do your homework and take the test.

John, another student, said that sustainability and global climate change were discussed in the sustainability elective class, but otherwise were only talked about in one other class, senior design. I observed the senior design class, and the professor specifically said that he was not going to discuss climate change and if it was or was not happening but instead would talk about other reasons it was important to think about sustainable design. John and I talked about that day in class.

> John: My other ones, there have been some I guess. In Dr. Ebert's class there has been, he's assigned writing assignments and project aspects that incorporate sustainability which I think is great. I'm really glad to see that as much as people who receive that assignment might just think it's stupid. They at least have time to evaluate it and hopefully with their engineering minds, they can see the science behind it more and more. That was another one, a good one, climate change and carbon footprint. I guess Dr. Ebert has mentioned specifically carbon footprint. But I think climate change specifically, explicitly, I have only heard from Dr. Petrotich in my current class.
>
> Maria: I thought that was an interesting move on the sustainability Dr. Ebert was like, "I'm not going to tell you one way or another about global climate change but we're going to talk about this concept" and I thought that was an interesting rhetorical move.
>
> John: I agree. It's so political. It's so political that I mean I'm not surprised no one has mentioned it. I also haven't heard much about religion.
>
> [laughter]
>
> John: Or conservative and liberal anything about that. For some reason it's so connected to that.

This conversation is a good example of an engineering class not focusing on cultural or social scientific subjects. The professor did talk about sustainable design but wanted to navigate away from the controversial subject of climate change. Professors have already mentioned that they feel insecure talking about the subject, and the culture assumes that engineers do math and science and do not have to concern themselves with political topics. In fact some participants felt that engineers were victims of a political system. One participant said,

> Unfortunately for us engineers, we don't have a lot of political influence because that's just not our time. Our time does not allow for us to go and say we want this, we want this or we think this. Also, a lot of time what happens is you get political buyoffs. You see scientists get kicked a little something to say

something is this way, which sucks.

This contradiction of identity emphasizes that engineers do not view themselves as actors in the political process. At a macro-level, they do not see engineers engaged in political processes. However, governmental funding, policy formation, and compliance are an important part of the job. I will give an excerpt from a conversation between an engineering professor and myself. The context of this conversation was how funding and grants drive decisions requiring curriculum and research.

Dr. Lewis: And there aren't very many engineers in Washington...

Maria: Right.

Dr. Lewis: Who are pushing these issues.

Maria: I think I read that there is one House of Representatives member.

Dr. Lewis: I think there's one.

Maria: Yeah.

Dr. Lewis: One engineer.

Maria: Pretty amazing.

Dr. Lewis: Yeah it is. When you think about how pervasive engineering is in our society…

Maria: Right.

Dr. Lewis: That we don't have anybody in Washington pushing the agenda.

Maria: And that they're taught to be thinkers, right?

Dr. Lewis: Yes. And problem solvers right? And that's a good trait to have if you're in Washington trying to sell all these tough, tough problems in a political environment.

This conversation sums up the contradiction so beautifully. Engineering is impacted by policies and decisions made in Washington; however, most engineers are not attracted to the political process and few hold office. Engineering is housed within a system of government, a system of commerce, and a system of education. These are all linked and depend on each other. Regulation and funding are important. Listening to these engineers, they understand that politics and policies are important to their careers and have a significant impact, especially when it comes to sustainable design. However, it is not a subject of interest and certainly not much attention is given to politics in the socialization process. It is implicitly understood to be important, but it is not often explicitly talked about, so although policies have a great impact, little about them is addressed in class.

Most participants claimed they had little interest in being political or having politics impact their careers. However, by pursuing grants and having to design according to policy specification, politics are implicit and important to the job. Interestingly, professors and students said that engineering education is focused only on science curricula and that they regarded global climate change to be a social issue. However, 97% of climate scientists agree that human-caused climate change is occurring (National Aeronautics and Space Administration, 2013). This scientific agreement should change the nature of discussion around climate change from one of a social issue to one of scientific fact. Climate change is science and thus should be incorporated into the discussion much like physics and mathematics. Addressing climate change as a scientific discourse could serve as a resource to understanding the concepts in a field that values science. Many professors felt comfortable teaching subjects that were based in science and math, but not so confident in the subjects that are more social in nature. The idea of teaching socially controversial topics did not fit into the identity of many engineering professors. So the larger contradiction manifests at the individual level and is managed by individuals focusing on being nonpolitical.

Professors expressed nervousness about teaching content that could be construed as controversial. Teaching math and physics is a very different process than teaching a class about social issues. Leading a heated discussion about a controversial issue is difficult, and mechanical engineering professors are not given training in leading such discussions and teaching material that is not traditionally in their specific area of expertise. This can be anxiety producing, and many professors expressed uneasiness with that process. These professors have absolute faith in math and physics, but subjects outside of those areas are daunting. A discussion with a professor who has taken on teaching ethics demonstrates just how intimidating teaching a controversial subject can be:

> Dr. Petrotich: Let me tell you the first time I walked into the class I decided to teach on engineering ethics to give my first lecture, I was freaking out.
>
> Maria: I bet.
>
> Dr. Petrotich: Yeah, what am I going to talk about you know? Wow. To go through this and try to get a coherent future. But you know, one of the things I found in studying ethics and looking at it from different perspectives and try to think about how do I quantify ethics, okay? Because engineers quantify.How do I quantify it?
>
> Maria: I wouldn't imagine in the training or the graduate experience, of becoming a mechanical engineering professor, there's a lot of opportunity to teach controversial…
>
> Dr. Petrotich: No.
>
> Maria: Classes.
>
> Dr. Petrotich: None. Zero.
>
> Maria: I can imagine that's a really scary thing to say, "We're going to talk about global climate change today" and be ready for that as opposed to "We're going to talk about this law of physics" that's not really controversial.

> Dr. Petrotich: No, well, we try to avoid it. We go with things that are known and again, engineering pulls in.
>
> Maria: Yeah.
>
> Dr. Petrotich: People that want their world to be very exact, predictable.
>
> Maria: Yeah.
>
> Dr. Petrotich: Things like reality, it's all over the map.
>
> Maria: Yeah.
>
> Dr. Petrotich: How do you define that? What do you, do you define as ethics and who is in charge? Who gets to make the rules? It was between relativism and absolutism. Like it just boggles the mind so engineers don't want to think. Let me go back to my class where I can do calculations and heat transfer because it's so much easier when a number comes out of the end of it. Part of our problem I think with engineers is that they preselect the people that don't want to have the material on the outside, it gives them conflicting ideas up for discussion. They want the world to be more precise. That's where it is. That's where maybe the biggest problem is. Questions of sustainability. Questions of human trajectory. Questions of risk assessment and how do you value this to life? Is it different if it's five people or five million people and engineers don't really want to talk about it. I'll tell you they would hate it if they were forced to take a class in it.

This is another example of how broader national and international discussions of climate change are impacting these individuals at the Mountain State University. The climate debate has focused around whether it is occurring or not, the science has not been communicated in an understandable way. This broader discussion has transformed a conversation that should be about science into a controversy impacting the content that individuals decide to talk about in class. The macro-discussions of climate change impact the micro-actions of professors. If the micro-conversations professors have in classes with students emphasized the science of climate change instead of the controversy, there is a possibility that the macro-conversations about climate change could shift as well. Basically, since the engineers “self-select” as interested in quantifiable data, they see themselves as outside of politics and thus unwilling (and/or in the case of the professors, perhaps unequipped) to address the larger issues society is increasingly calling them to consider.

The Gendered Nature of Engineering and Environmentalism

Another contradiction relating to identity is the gendered nature of mechanical engineering and how the discipline's very masculine milieu equates environmentalism with the feminine. The idea of gendered organizations (Acker, 1990; Britton, 2000) postulates that organizations are sites in which dominant gender identities are created and recreated. Additionally, it is commonly pondered why women are underrepresented in the field of engineering (Frehill, Benton-Speyer, & Hunt, 2005). Mechanical engineering is a masculine profession, particularly so at Mountain State University. In 3 years that I observed the ME EN 4000 Senior Design class, the capstone of the ME undergraduate curriculum, the class averaged 100 students and 4 ME teaching assistants. In this large auditorium classroom there were never more than 10 women in the classroom including myself. It is a male-dominated field. Josh, a professional engineer whom I interviewed, said, "There's a huge lack of women in engineering. It's a very male-dominated scene, I don't know, an imbalance I think." Professor Petrotich wondered why Mountain State University had such a low percentage of women in the mechanical engineering program:

> Here in mechanical engineering at Mountain State University, it's like forty percent. We are just not attracting women to our program. I don't quite understand this part of the culture here. But I'm not really sure that we're connecting and we're not being able to get women to see that this is a place where you can make a difference. Where we can come up with technology that does meet the unsustainable future.

This quote alludes to the idea that one reason women are not attracted to mechanical engineering is because they don't see it as a place they can fit and make a difference.

To pursue this idea further, the idea of being an environmentalist or an "earth mother" is often connected to the feminine. There is the popular idea of the Earth itself as a mother, and environmentalists are sometimes conflated with "flower children." Often men who identify as environmentalists are thought of as not masculine, being vegetarian or driving "wimpy" cars (Rogers, 2008) . When asked about the importance of sustainability in engineering, John, a student, said (with humor and truth), "Why would we care about that? It is a girl, hippy thing to care about." This idea of environmentalists as earth mothers and engineers being a masculine in a masculine profession is a contradiction between images of self-identity. A binary is created in identity. As Professor Lund said,

> And this goes back to the idea about the masculine/feminine stereotypes in engineering/environmentalism – within engineering, I wonder if it is really the math issue that affects women so much, or the more generally accepted idea that men are more logical thinkers while women tend to be more emotional and flighty (i.e., the speaker addressing climate change with poetry).

This contradiction is one that leads to a conflict in identifying as both an environmentalist and an engineer while not being thought of as feminine.

Professor Petrotich took the idea one step further. When I asked him if he thought the very nature of the profession of mechanical engineering impacted the way that engineering was responding to sustainable design, he went deeper and said that even the way that energy is extracted is gendered.

> Dr. Petrotich: If you think about fossil fuels versus renewable energy, and nuclear, some of those energy forms are very natural, some of them are very feminine.
>
> Maria: Yeah, absolutely.

> Dr. Petrotich: When you start to look at this, you just have to wonder, it's something about this huge coal mining machines and drilling these well ten thousand feet down in the ground and setting up controlled nuclear reactions. I mean bombs, stuff like bombs, setting off explosions on the inside of your car. There is this kind of masculine thing that goes on with oil and coal and fossil fuel. Huge amounts of earth that you gain incredible energy. It's kind of a guy thing. And if you look at a solar collector…
>
> Maria: It's almost like photosynthesis, like a flower growing.
>
> Dr. Petrotich : Yeah, like a windmill; really like a big wind flower.
>
> Maria: The wave you know, it's fluid and it's…
>
> Dr. Petrotich : Yeah.
>
> Maria: I think about it a lot.
>
> Dr. Petrotich : Yeah. Constant energy but just dispersed. I've always felt that you could probably sell more Priuses if you make them sound like Harleys because part of the problem is they're so quiet. I don't think guys like quiet cars. You'd probably have a great business selling little speakers under Priuses that have different switches that would go like vroom vroom.

This contradiction is that the masculine identity of the field of mechanical engineering and the feminine idea of the environmentalist are at odds with each other and can be difficult for students to navigate as they are being socialized. Neophytes desire to be good engineers, and if feminine attributes are not part of engineering, then it becomes difficult to house both identities in the same individual. The two attributes become contradictions. Interestingly, the department wants to attract women. They have initiatives to recruit and keep more female students, and yet only seven percent of the full major students are female.

An example of communication that may be hostile to women in engineering classes happened the last year I taught. In the ME EN 4000 Senior Design class there were 109 students in the class and 5 of those were women. In this class the day that the lecture on sustainable design was given, the first slide of the power point was a clothes line with many sizes of ladies underwear on it, on one end old bloomers large in size and on the other end a small thong (Figure 4.2).

This picture is meant to be a funny nod to global climate change, but it could be argued that in a room where women are a minority, beginning a lecture with women's underwear on the screen could make a female student feel uncomfortable. It certainly made me, one of six women in the room, feel self-conscious. This contradiction raises issues of gender, organizational culture, and self-reflexivity. This idea of gender roles is hardly unique to this mechanical engineering department. Again drawing on Rogers' (2008) article that describes three commercials that highlight how feminine and weak environmental men are, we can see how this organization and its individuals' identification of engineering being masculine are linked to larger structures of gender, which connects to a larger issue the field of engineering is having recruiting and retaining female engineers.

In addition to the idea of environmentalism being feminine, there are other counter-culture traits or characteristics associated with it such as being a “hippy,” “greeny,” or “liberal.” As Josh said, “I think one barrier to entry is that it started with the ecology and the environmental movement in the '70s and so it still gets the stigma of being very left wing, you're a “hippy,” you're a radical type concept.” The engineering students expressed not wanting to be associated with hippy culture.

This was expressed by Dr. O'Malley, who identified one challenge to incorporating sustainability into classes to be the association the concept has with liberal hippies:

> The big problem or the challenge that I see is the students look at sustainability and they're like, tree huggers, green, they're tired of hearing green, green, green. They want to know really what it means and if it really matters. Particularly

> because of all the strong controversy that exists in science about climate change, global warming and all these other factors. So it's a mixed message and it's received well by some students and completely kind of almost revolted against by others.

The term “hippy” is not one that is a badge of honor in this group. Not wanting to be associated with hippies is a concern of students trying to establish how they fit into the organization. When asking one student to define environmentalism it quickly became about hippies:

> Maria: Would you define the word environmentalism for me?
>
> Allen: The first word that comes to mind is hippies.
>
> Maria: It's fair.
>
> Allen: That's wrong.
>
> [laughter]
>
> Allen: That's not cool. I like hippies.

Professor Tolliaferro, who teaches sustainability topics, stated that his credibility is called into question when students meet him.

> Dr. Tolliaferro: It's interesting because I think usually by - so I have the students for two semesters, which is nice because the first of the first semester they look at me as though I'm some green, liberal, out there telling them to stop watching NASCAR. Then by the second semester they finally learn that I'm not telling them to do anything one way or the other as far as that goes.

This was also demonstrated as students described professors who teach sustainability topics. Dr. Petrotich, who is a vocal advocate of sustainable design and teaches classes regarding sustainable design and energy, was described as follows:

> Aaron: It does. Have you talked to the people who are doing the biomass gasification?
>
> Maria: No. That's part of Petrotich's group right? He's next on my list. I need to sit down and have a long chat with him.

Aaron: He's entertaining. He's kind of like the hippie professor.

Another professor was described as a "Green Peace type of guy." By valuing, teaching, and researching sustainability there is an "othering" effect that makes these professors and students who hold these values stand out as a hippy, an attribute others do not want to be associated or identified with.

One student named John expressed the contradiction eloquently:

> It's interesting, when you talk about those exact topics without using the word, it's really funny to see the reaction of people who would normally if you say, "Oh, let's talk about sustainability" and they're like "Aw, hippie!" That's all they hear or whatever. But if you say "well let's save our company money and energy use" it's so obvious like "Yes! Let's do it". That's all I know. My friends have various beliefs. A lot of my friends are more conservative than on the side of the anti-hippie idea. Guys in my study group and old friends and my family, all of them kind of if you bring up global warming, a little bit more of an emotional, political, maybe even religious reaction pops up. Talking about it with them, there's a lot more skepticism, there's a lot more belief in the ideas of, well less and less, that it's a myth. It's a girl, hippie thing to care about.

The term "cloistered advocate" is what I have named this phenomenon, or the way that participants are negotiating this contradiction. As we learned in RQ1, many of the students and professors identify as being sympathetic to environmental concerns. In fact many were not hesitant to talk about actions they take in their everyday life to contribute less pollution. Additionally, many expressed that they like the values of being environmentally aware. Even though they hold and express these beliefs, they do not want to be labeled an environmentalist. Through these interviews it became apparent that these labels ("environmentalist," "greeny," and "hippy") are what participants took issue with, not the values associated with them.

Our identities and the way we enact our identities are part of the organization or how things are enacted in the organization. The contradiction becomes about the individual's sense of self: "I am not political, but I have political thoughts, so I want to do this, but I don't want to do it publicly." These people are feeling that their identity is an intrapersonal battle, with sustainability equated with being feminine, but I am masculine; sustainability is political, but I am not political. This intrapersonal battle is connected to macro-ideas of what an engineer is and how they fit into society. It can become confusing. Participants handled this contradiction by expressing their environmental ideas as a cloistered advocate.

These individuals think of themselves singularly, as people who love machines, and stay away from social issues; however, they also indicate that they are environmentalists and care about the earth. Professors want to prepare students for future careers, but do not feel comfortable in teaching subjects that could be perceived as controversial. These students and professors are dealing with a great deal of tension as they create an identity of themselves within this career. In deciding to bring ideas of sustainability into the classes that they teach, professors can negotiate it a few ways. Some of them choose to be scholars who focus on sustainability; they are sustainability scholars, and they bring much of the information about sustainable design to students. Others find sustainability to be an important topic but because of a lack of time, expertise, or comfort with the subject do not make it part of the classes they teach. Others do not find it to be an important topic at all and have no desire to incorporate it into the coursework they teach. This range of attitudes toward teaching sustainability creates a mosaic of how individuals within the department are negotiating contradictions. Tackling global climate change is difficult, and this department is a good microcosm of what occurs in larger society.

To conclude research question 2, Table 4.7 summarizes the contradictions and how organizational members negotiate them.

Table 4.1: Analysis of student definitions of sustainability.

Year/Department	Concept of sustainability identified in definition	Number of answers	Percent of answers
Freshman/ME	Low Environmental impact	41	33%
	Long lasting design	19	15%
	Energy/fuel conscious	8	6%
	Designing with future generations in mind	8	6%
Sophomore/ME	Low Environmental impact	20	27%
	Energy/fuel conscious	17	23%
	Mindful of resources	14	18%
	Long lasting design	10	14%
Senior/ME	Long lasting design	17	29%
	Low Environmental impact	13	22%
	Reduce waste	10	17%
	Recycled materials	7	12%

Table 4.2: Do you think global climate change is occurring?

Year/ Department	Number of participants	No, I do not think it is		It is probably not caused by humans		I am not sure		I think it is		Without a doubt	
Freshman/ ME	126	5	.04%	9	.07%	24	19%	40	32%	48	38%
Sophomore/ ME	75	4	.05%	3	.04%	11	15%	28	37%	29	39%
Seniors/ME	58	3	5%	4	6%	7	12%	24	41%	18	31%

Because the surveys for the seniors and the freshmen and sophomores were different, I would like to explain how I reasoned the results. The senior survey was as is presented on this scale. The freshmen and sophomores had a Likert scale of 1 to 7, 1 being no I don't think it is happening and 7 being it is occurring without a doubt. Because of this, I analyzed the results of the freshmen and sophomores as follows: answers of 1 were categorized as it is not happening. Answers of 2 were it is probably caused by humans, answers of 3 and 4 were I am not sure, answers of 5 and 6 were I think it is and an answer of 7 was without a doubt.

Table 4.3: Classes that provided instruction in sustainable design

Year/Department	Class that taught them the most about sustainable design	Students who said they had taken no classes that deal with sustainability	
Freshman/ME	ME EN 1000 E LEAP	90/126	71%
Sophomore/ME	ME EN 2500 E LEAP	12/75	16%
Senior/ME	Senior Design Sustainable Energy Thermodynamics Heat Transfer	22/58	38%

Table 4.4: Summary of student responses that listed sustainability as a top 5 design consideration.

Year/Department	Number of participants	Number who listed sustainability or environmental concerns	Percent who consider sustainability or the environment in design process
Freshman/ME	126	3	2%
Sophomore/ME	75	6	8%
Senior/ME	58	6	10%

Table 4.5: Number of correct answers for 5r's and triple bottom line.

Year/ Department	Number of Participants	Number of correct answers for 5 Rs	Number of correct triple bottom line	Percent of correct answers
Freshman/ME	126	11		9%
			18	14%
Sophomore/ME	75	22		29%
			25	33%
Senior/ME	58	16		28%
			16	28%

Table 4.6: To what extent is sustainability important in your personal life?

Year/ Department	No. of particp's	Not at all important		A little important		Important		Very important		Extremely important	
Freshman /ME	126	3	.02%	13	1%	44	35%	37	29%	31	25%
Sophomore /ME	75	1	.01%	10	13%	35	47%	12	16%	14	19%
Senior/ME	58	0	0%	13	22%	19	34%	17	29%	9	10%

Because the surveys for the seniors and the freshmen and sophomores were different, I would like to explain how I reasoned the results. The senior survey was as is presented on this scale. The freshmen and sophomores had a Likert scale of 1 to 7, 1 being not at all important and 7 being extremely important. Because of this, I analyzed the results of the freshmen and sophomores as follows: Answers of 1 were categorized as not at all important, answers of 2 and 3 were a little important, answers of 4 and 5 were important, answers of 6 were very important and answers of 7 were extremely important.

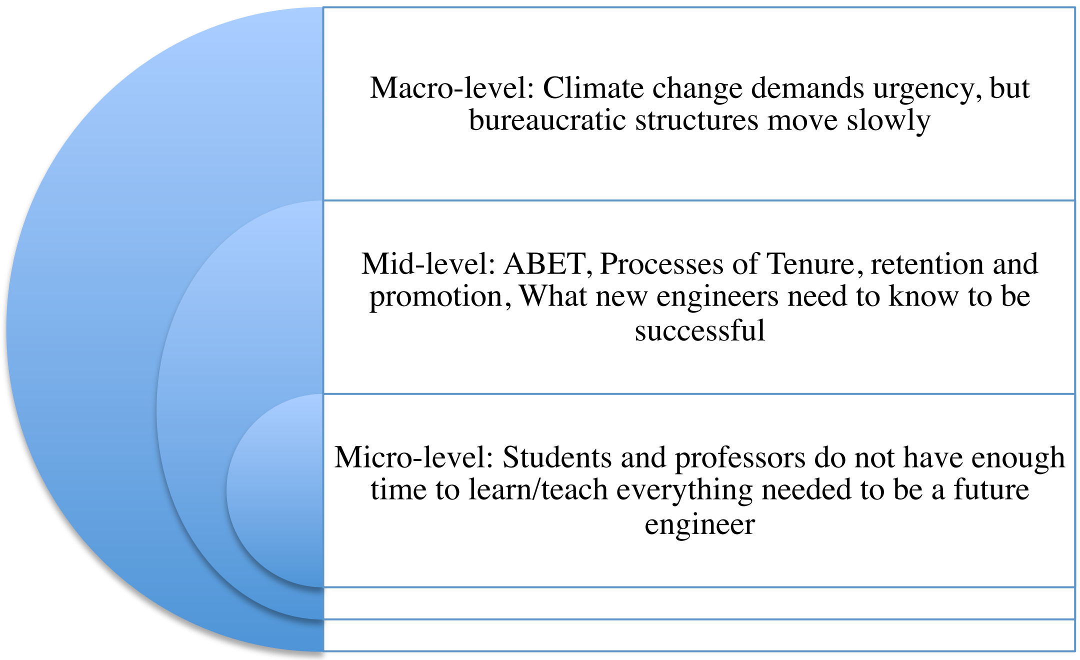
Table 4.7: Summary of contradiction analysis

Level of Analysis	Contradiction	Type of Contradiction	How it is Negotiated
Time			
Macro-level institutions	**Time** Urgency of climate change v. Slowly moving academic schedule	**Secondary Contradiction** Time is both limited and limitless	Feeling overwhelmed by organizational processes and time constraints. Prioritizing traditional behaviors and rewards.
Mid-level institutions	**Accreditation process through ABET** ABET requirements are created as a resource but perceived as a nuisance	**Secondary Contradiction** ABET accreditation is both required and ignored	Some program requirements are privileged Accreditation standards are met, but ABET is not being used as a resource for course design Accreditation standards are justified after classes conclude
	Systems of Tenure, Promotion, and Retention The difference between what it takes to provide a quality engineering program and the tenure and promotion process	**Secondary Contradiction** The difficulty between performing the necessary functions to staying employed in the academic system while creating new class content	Tasks necessary to achieve tenure are privileged over other tasks
	Future of ME education What is necessary to be a well trained mechanical engineer is being challenged by new subjects gaining importance	**Tertiary contradiction** Newtonian physics and math are still important, but other subjects have gained in importance	Programs and professors are expanding what students need to know

Table 4.7: Continued

Level of Analysis	Contradiction	Type of Contradiction	How it is Negotiated
	Compartmentalizing sustainability A few specialists in the department so everyone does not feel they have to teach the subject	**Primary contradiction** Because a few faculty members are appointed the "people who do sustainability," the expertise in the department is compartmentalized	A few specialized professors teach the majority of sustainability Others can focus elsewhere
Economic Structures			
Macro-level institutions	**Economic structures** Initial expense of a design verses long-term cost	**Secondary Contradiction** Tension between profitability and collective good	Initial expense of the design trumps long-term cost A few professors teach the concept of externalities
Mid-level institutions	**Funding** How academic departments are funded has changed from public funding to grant driven	**Tertiary Contradiction** Procuring outside funding is a new and necessary part of academic responsibilities sometimes prioritized over teaching	Unless the grant is focused on sustainability, the subject is ignored in the grant-writing process Professors would change behavior if there were a reward for sustainability in the grant-writing process
Identity	**Identity** Identity of organization members is in contradiction with that of the organization	**Primary contradiction** The expectations of the organization do not match the identity the individual has of themselves	Cloistered advocacy

Time



Economic

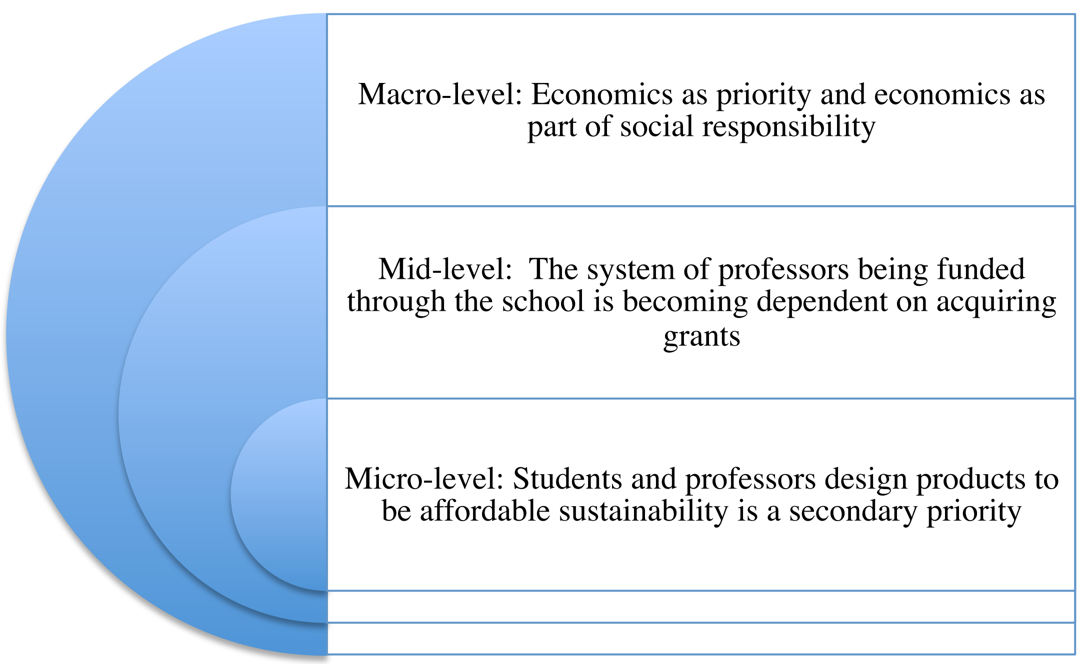


Figure 4.1 Illustration of the interplay between the macro-, mid-level, and micro-contradictions that occur within the major contradiction categories of time, economics, and identity.

Identity

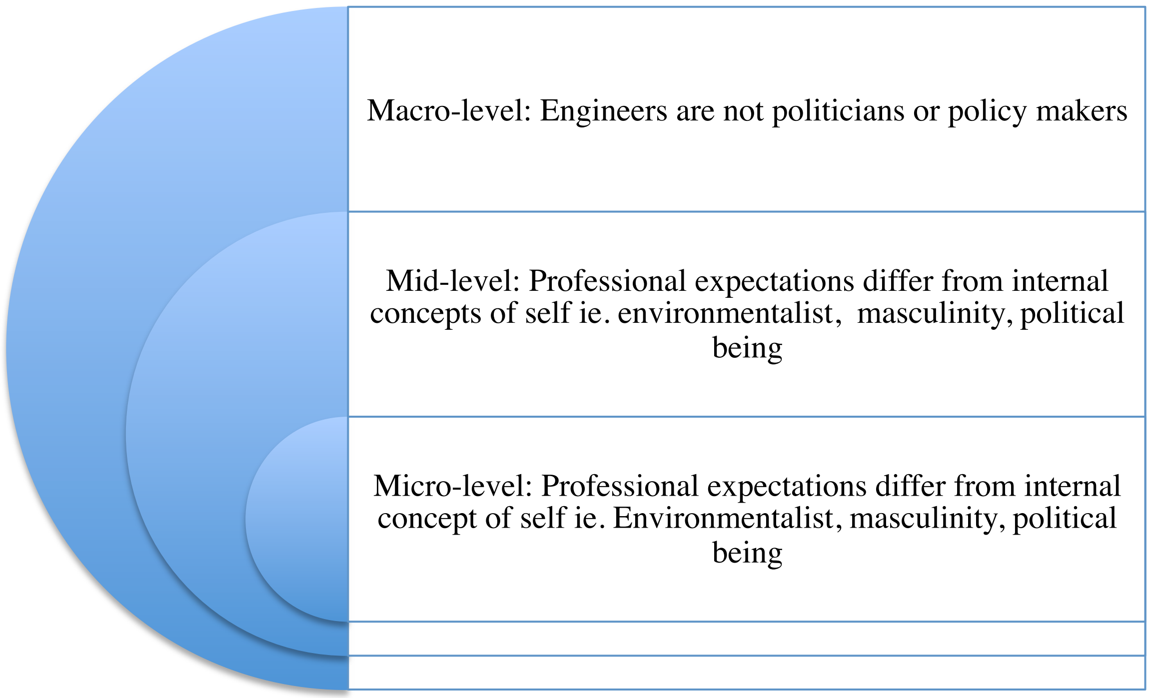


Figure 1 Continued

Figure 4.2 The image shown at the beginning of the sustainable design lecture.

CHAPTER 5

DISCUSSION

The goal of this project has been to understand how an organization that is in the midst of change socializes members into a new of way of doing things. This study has integrated structuration theory and structurating activity theory (SAT) to identify relevant contradictions to help understand the complexities of organizational change, especially in the face of global climate change. Specifically, this integration has been conducted by identifying contradictions, classifying them (as primary, secondary, tertiary, or quaternary), and determining where they are located (within the macro-level institution, mid-level institution, or micro-level). The interplay between them has offered a way to view change that helps to theorize more precisely the kind of change that has been called for in the engineering industry. By identifying contradictions, what kind they are and the rules and resources available, a new way of enacting organizational change is introduced.

Summary of Findings

Research Question

The first research question sought to identify the department's means of making sense of sustainability. Most members of the department recognize that sustainability is an important part of the design process and must be incorporated into the education process. Because of this, the department has taken many steps to emphasize sustainability in the curriculum. One significant step is having several faculty members who focus on teaching sustainability. With faculty who focus their research on environmental manufacturing, alternative energy systems, and energy efficiency, students have the opportunity to learn from people involved in thinking about using resources in a new way. These professors offer elective classes that focus on sustainability, building knowledge and skills in students and socializing them to value sustainability. The fact that the department just hired a new faculty member with this specialty demonstrates a strong commitment to the subject and a desire to expand this area of learning in the program.

The department also demonstrates a commitment to sustainability by offering the content through classes that have a focus other than sustainability. The ELEAP program offers students the opportunity to learn to write, work in teams, and give presentations while learning about sustainability. The senior design class has incorporated a lecture about sustainability and created assignments that foster thinking about the subject. Last, the creation of the spiral 1000- and 2000-level program that incorporated sustainability into the thermodynamics curriculum was an attempt to introduce sustainability to students by integrating the subject into existing classes.

Many of the participants indicated that they identified as environmentalists on some level. They said that in their personal lives and in recreational endeavors, they embrace principles such as leaving a place better than you found it and not littering; furthermore, many of them realized that natural resources are limited. Their relationships with sustainability were more complex. Many of them defined sustainability as the process of minimizing environmental impact, saving resources for the future, creating a design that is long lasting, and being energy/fuel conscious. However, many were skeptical of the term and were concerned it was a buzzword or the product of a green-washing effort. A small minority could not see how sustainability was a concept that had any connection to engineering design. Last, through surveys it was demonstrated that some concepts associated with sustainable design, such as cradle-to-cradle design and triple bottom line, were known and understood by some of the students, but they were not concepts that every student could define. With this understanding of how the department is making sense of sustainability, the contradictions identified in this project will be discussed.

The second research question asked about how contradictions were being navigated. In this question, three major categories of contradictions were identified, as were rules and resources that might be valuable in addressing the contradictions. Most organizational-level contradictions discussed were embedded in macro-level contradictions that included two categories: time and political-economic structures. The third major contradiction involved the identity of engineers.

First is the issue of time. This contradiction is the urgency of the need for change coupled with the slow bureaucratic timing of change in academia. Positive developments regarding sustainability are happening in this department to facilitate a new way of socializing engineers. However, the issue of climate change has a timeline. This study has highlighted that changes are occurring in the department, but they are not happening at a rate that matches the urgency of climate change.

ABET and the tenure process are both mid-level contradictions connected to the macro-contradiction of time. ABET has identified and understood the need for sustainability to be part of the design process. The criteria have been established based on feedback from governments, industry, and universities. They develop criteria so that engineers who have been socialized by accredited universities have a baseline understanding of certain concepts. It appears that ABET is viewed as a necessary inconvenience for which reports must be constructed, instead of a guiding principle. The current system of tenure and funding emphasizes and rewards grant acquisition, publications, and student reviews, while it offers less recognition to the incorporation of new elements into classes. Indeed, a failure to produce results in grant acquisition and publications can end an academic career. Because professors will not receive a reward for incorporating new content into classes, and because they face little professional risk for not doing so, they are not motivated to change behavior.

Economic issues were the other macro-level contradiction. This contradiction stems from economic successes being viewed in tension with greater social good. The interplay between the micro- and the macro-economic issues was very evident in this subject. There was a great deal of discussion about economic markets dictating the actions of the engineers. Participants ere open to designing in a more sustainable way—if someone would pay for it. This conversation centered on the additional cost associated with sustainable design, and few participants prioritized sustainability over the cost of the design.

Connected to the macro-level economic contradictions are two mid-level contradictions relating to funding in academia generally and in the field of engineering specifically. The goal of most participants was to get jobs, be promoted in them, and create successful relationships with organizations. Participants stated that if there were economic rewards built into systems for being sustainably focused, such as being more qualified for a job or being eligible for a higher pay grade, participants would be more interested in learning about sustainability. The realities of capitalism inform how systems reward individuals and thus have an impact on their decisions.

The third category of contradiction relates to how individuals conceptualized their identities as engineers. This study revealed contradictions among several aspects of the engineers' identities. The first was that engineers did not think of themselves as political, and yet many aspects of their work involved political issues. The second was that engineering is often conceptualized as a masculine profession, yet environmentalism and sustainability have a more feminine connotation. This contradiction addresses the difficulty of incorporating sustainability in an engineering context because of the gendered nature of the two concepts. The third was cloistered advocacy, in which many of the participants identified with environmentalists and participated in activities they would consider to be advocating for the planet, but did not want to call themselves such because they associated negative attributes to the environmentalist label. Another primary contradiction was that many professors stated they were uncomfortable teaching subjects that veered away from math and science. Considered together, these contradictions reflect that the way individuals see themselves and their roles in the organization is in contradiction with their notion of sustainability. This is how members of this organization made sense of sustainability and the contradictions that they are negotiating within the organization.

Rules and Resources in Organizational Change Processes

The complex interweaving of contradictions on multiple organizational levels provides an opportunity to reimagine how change occurs. Identifying contradictions gives the chance to identify theoretically where change initiatives could be most successful. Significantly, not only is it important to identify the contradictions, it is also necessary to identify what rules and resources are in existence, and what rules and resources are necessary to create a structure that can support change initiatives. Simply communicating the desire to do something different does not effect material change; however, with the further identification of the rules and resources necessary for its support, perhaps the change will take hold. After rules and resources are discussed, the process of using the identified contradictions and rules and resources will be used to make recommendations.

Often, as organizational changes are implemented, there is not a consideration for the resources available to enact the change. An example of this was the spiral classes implemented in the curriculum to bring more sustainability education to students. Although these classes were well conceived, there was little consideration of the resources required to sustain this new mode of instruction. Hence, instructors were not given enough time to re-create the curriculum to incorporate sustainability in a meaningful way, and the concept was discarded. Now the history of the spiral classes can serve as a resource for the future as people make sense of this earlier attempt at change.

Reexamining the list of obstacles to including sustainability in engineering programs that was presented in Chapter 2 reveals that many of these are connected to rules and resources being unavailable for change:

Maturity of the students;

Knowledge of sustainability and the environment among lecturers;

Lack of acceptance of sustainability engineering;

Discomfort with interdisciplinary teaching;

Lack of textbooks;

Not knowing where to acquire relevant information;

Difficulty combining environmental and sustainable design information with core curriculum;

No reward for the extra work and innovation;

A perceived threat to ideas of territory;

Worry that environmental understanding is not appropriate for their discipline;

Lack of access to examples;

Lack of support;

A feeling that change is daunting;

Lack of time to create new lessons. (Boyle, 2004; Thomas, 2004)

Most of these mention a lack of resources (textbooks, time, knowledge, support, and information) or insufficient access to them. Although not explicitly stated to be matters of rules, perceived threat to territory and appropriateness for the discipline both involve the rules of the department or the unwritten rules of the culture. In addition to identifying contradictions, I argue that detecting the rules and resources available to actors within the organization offers a way to create a change plan that can be supported by the organization. By considering the rules and resources, the structure will be able to support the implemented changes.

At this site, the mechanical engineering program has several rules that influence socialization. Literal rules emerge from entities such as federal regulatory agencies, granting organizations like the NSF, accrediting institutions such as ABET, and the Mountain State University itself, which established institutional guidelines for graduation and tenure. Other rules include the norms, behaviors, and expectations of members of this organization. Thus, organizational rules range from the number of credit hours one has to take to receive a degree, to what assignments are given to pass a class, to what projects will suffice for the senior design project, to how a member of this organization is expected to speak in class. All of these rules impact the actions and choices of the actors, whether they choose to reinforce or challenge them.

Rules were often spoken of as restraints to action, while regulations were perceived to limit grant funding and confine the teaching and availability of classes. Other rules, like those discussed in the contradiction about identity, set a standard for behaviors, such as being apolitical or using masculine communication tactics. In the Suggestions for the Mechanical Engineering Program section later in this chapter, I propose that reconsidering rules could help engineers better address sustainability in the design process.

More noticeable than rules present within this organization are the lack of rules regarding how sustainability is taught. There is not a written departmental mandate or rule for incorporating sustainability into instruction. Instead, operative rules encourage avoiding time-consuming and controversial topics. This reinscribes adherence to the status quo. Additionally, because sustainability is a specialty expertise, those who do not identify as sustainability scholars do not need to address sustainability in their classes. There are no rules that structure how sustainability is taught in the department, while rules of specialization effectively relegate the teaching of sustainability to subject-specific electives. Because of this, many students are not exposed to sustainability.

Also interesting was the participants' tendency to discuss rules as a limitation to success, particularly regarding environmental regulations. The responses of participants indicated that they were wary of environmentalism when they perceived it to entail the addition of rules and regulations to the design process. These rules are considered by many to hinder creativity and profitability, making rules a constraint on the design process. Rules, however, are not simply an obstacle. Rules help create the structure of a given project, and they can restrict or enable new ways of doing things. Engineers are focused on math and science, a convention that amounts to a rule limiting the ability to talk about social issues and how design can have an impact on them. In many ways, limiting the identity of an engineer limits the ability to design. The example of using biology in the design process is a good demonstration of this. The more students know about biology, the more inspiration can be gleaned from nature; however, the already packed schedule of an engineering student does not leave time for biology classes. Exposure to ideas and disciplines outside of engineering offers more avenues of exploration and creativity.

Throughout the course of this study several resources were identified that could be used to facilitate change in the way that newcomers are socialized. The first resource identified is the neophytes' beliefs and values. There is great importance in most of the participants conceding on some level to being environmentalists and believing that global climate change is occurring. Although most did not identify as environmentalists, many interviewees did hold an environmental ethic. Many participants valued the environment and performed actions in their personal lives that they consider environmentally engaged. Many individuals already see value in environmental principles that could be a resource for teaching sustainable design. Additionally, most professors saw the importance of the subject and believed climate change was happening. With a group of people who are unopposed to these ideas, sustainability can be incorporated into the curriculum at a level in which the remedial step of establishing the existence of global climate change becomes unnecessary. In this group are also champions of the cause. There were both students and professors who were passionate apostles of the importance of sustainability in the design process. These leaders serve as individuals who will impact structures through actions that create change. A few individuals making micro-changes can have impacts on larger structures.

Understanding the importance of these champions is another resource in this department. Making strategic decisions in the hiring process to bring aboard faculty with expertise in sustainability creates opportunities for knowledge sharing and the acquisition of more resources through grants. Allocating departmental funds to have these individuals on staff is a resource for sustainability. Interestingly, this serves as both a resource and a contradiction. As mentioned earlier, since the rest of the department often looks to specialists to "take care" of all of the sustainability responsibilities, the presence of champions of sustainability in the department risks compartmentalizing the subject.

The Mountain State University itself is a resource for this program. The university has made sustainability a priority to the campus. Through this, faculty and students have access to knowledge, support, and money for the subject of sustainability. There are interdisciplinary certificate programs, and the Office of Sustainability supports building knowledge of sustainability campus-wide. Activities like an Earth Day celebration or guest lectures allow students to acquire information outside of their programs of study.

Although ABET has been discussed as a rule maker, it could also be a resource. By reframing the accreditation process, ABET standards could offer an opportunity to restructure curriculum taught in classes to include more sustainability education. This could allow faculty to be imaginative in creating assignments, case studies, and lesson plans to shift them to cover more of the social aspects of mechanical engineering. Other resources available to the department to increase sustainability education include lab space, elective courses, faculty members who are dedicated to incorporating ideas of sustainability into coursework, and ELEAP.

Another, less tangible, resource available to the department is the willingness to try new things to incorporate sustainability into classes. A lecture and assignment about sustainability were added to the senior design class through a recommendation. The 1000- and 2000-level spiral classes were introduced to the mechanical engineering program to incorporate ideas of sustainability and served as an interesting case study of how change is implemented but sometimes is not lasting. This spiral class operate as a prime example of a change attempt that did not have resources provided to sustain the change. Throughout my research, individuals in the department were excited about this new approach of teaching and learning. The 2000-level classes in the spiral especially were going to merge several important topics, many of them recommended by ABET. Communication, writing, and sustainability were all going to be part of the class, which would also handle concepts like energy and thermodynamics. However, after 4 years, the class has been dismantled. As discussed in the results, many participants, both professors and students, felt that the subjects were not truly integrated and the cursory mentions of sustainability were almost distractions because meaningful connections were not made. With that said, the class offered assignments such as the train project, in which sophomores built a zero-emission toy train, and the sustainable design research project that got students thinking about sustainability. Professors talked about using externalities to expand thinking about economics.

Although this endeavor was an interesting new approach to teaching and funded in part through an NSF grant, ultimately, the class was dismantled and returned to the original format. Many participants noted that the class lacked resources such as time to reconstruct the course with more sustainability-focused lessons and the activities and lessons necessary to connect all of the concepts. When the course was not successful, it was reverted to a more traditional way of teaching.

Repeatedly, data showed that the individuals involved in the mechanical engineering department at the Mountain State University were curious, intelligent actors who hoped to make a difference in the world. This is an enormous resource. They are caring people who want to make a contribution to the world, placing safety at a premium. As one professor said, “Engineering is a profession that [is] number one. It provides services for the betterment of the public, more than any other profession.” It was apparent that both faculty and students shared this belief. Additionally, engineers see themselves as problem solvers. As Professor Petrotich talked about engineers being involved with new ways to use and produce energy he said:

> Engineers are optimists. Give us an opportunity to fix the problem and we'll fix it. It's not that big of a deal. We could produce all of the energy we need in this United States by covering a patch of some federal land somewhere south, southwest with solar reflectors, a hundred miles by a hundred miles. If you look at it on a map of the United States, you can't hardly even see it.

Overwhelmingly, the participants in this study viewed their role as engineers to be that of problem solvers. This resource should not be overlooked and could be infinitely useful in the face of climate change.

Some of the discussion of resources revolved around the lack of them. Global climate change, deforestation, and the current rapid and substantial extinction of species are caused by stretching the natural resources of the planet. This study highlighted that the resource of human capital is also being stretched. Organizations consistently ask members to do more with less. Both students and professors spoke of being asked to do a tremendous amount of work. Faculty spoke of the expectations to write grants, publish research, and create and teach classes while achieving high evaluations from students. Students talked about managing a rigorous course load, working outside of school, and having a family. These individuals did not feel that they had time to incorporate more into their lives. We have professors, students, and practicing engineers with a dearth of time for creativity, thinking, and devising new ways to approach learning. In interviews after being awarded the Nobel Prize in physics in 2013, Peter Higgs noted that the level of productivity that is expected in present-day academia would not have given him the ability to think deeply in the way that he needed to. He said, "It's difficult to imagine how I would ever have enough peace and quiet in the present sort of climate to do what I did in 1964" (p.1). Having the time to think about new ways of being is hard to come by in structures, systems, and organizations that ask individuals to manage a terrific workload.

Identifying resources available and resources needed to help build new structures proves to be an important part of creating change. This is another benefit to using a theoretical approach to changing curriculum. Using structuration, existing rules and resources can be uncovered, and rules and resources that are needed can be identified.

Practical Application

A healthy reluctance to depend on technology to solve all environmental issues is good. Clearly, a holistic approach that includes changes in actions, policies, and practices is necessary. However, those changes do not seem to be occurring. More and more reports about climate change are released that are increasingly urgent about the need for action. The effects of climate change are looming closer, as inhabitants of island nations such as Micronesia, the Marshall Islands, Palau, and Kiribati wonder at what point they will need to look for a new homeland, while hope that a solution can be found continues to diminish. Thus, to technology we turn, though it is naïve to expect technology to offer a panacea.

There is a great deal of debate regarding how to encourage more thought and action regarding the environment. Tactics including working within the system using legal action, arranging protests, improving environmental education, and staging image events (DeLuca, 1999) have all been attempted. The latter are what many of the people I talked to connected with being an environmentalist. They did not want to be thought of in conjunction with "hippy, greeny, liberals." Because of that, I would recommend choosing terms and words carefully as concepts of sustainable design are presented. Concepts such as safety, reliability, or quality, which are already important to this group of people, would offer new ways of framing that individuals could embrace. Professor Petrotich said that he framed discussion of sustainable design by using economic concepts of externalities. Students who might resist an association with environmentalism could nevertheless support economics as the foundation of sustainable design.

This might be a strategy embraced by more environmental groups. Much like Shellenberger and Nordhaus (2004) argue, environmentalists need to reframe arguments to attract people to take action. Those who identify as environmentalists know there is a large difference between a membership in the Sierra Club and a membership in Earth First!. However, those outside the movement lump them all together as "environmentalists," and if they cannot imagine themselves chained to bulldozers or living in a redwood tree, they cannot imagine themselves as environmentalists. Emphasizing goals like clean air or water for the health of human beings may be a better strategy.

The second application of this study is that although the advantages of mechanical engineers focusing on sustainable design has material consequences, every discipline has the opportunity to incorporate a more sustainable way of studying its respective subject. The insights of this study may shed light on general dynamics faced within many disciplines preparing students to communicate about climate change in a new way.

A good example of how an existing resource could be used to reframe so that sustainability could be further embraced would be that of safety. Overwhelmingly, the engineering students and professors mention that safety is one of their main priorities, yet although sustainability is linked to health it is not explicitly linked to safety. Research question 1 outlined how many students listed sustainability as one of their five main design priorities. No more than 10% listed sustainability. Safety was listed as important more often; in the 2000-level class half of the participants listed it as important.

Currently, safety is thought of separately from sustainability. Safety is conceptualized by thinking about a specific product being designed and whether it will injure, hurt, or kill the user. This idea of safety does not extend to long-term safety issues like the effect of pollution on respiratory health, nor does it extend to safety for nonhuman entities such as animals or plants. The purpose of moving to sustainable design is to mitigate the effects of climate change, reduce pollutants, and create less exhaust from products. On a meta-level all of these actions are for safety, to improve the health and environment of people and the planet. One student noted the connection between safety and sustainability in our interview:

> John: But there's so much external that we miss. I mean yes people won't die because this machine won't explode, but the toxins that release are causing all kinds of other important problems. The other thing is releasing toxins into the environment is going to have a negative effect on what we value no matter what, somehow. Even if we don't see it and we don't see exactly, okay, you know this toxin's causing this, it's being released by this company. You still have to be able to

accept that it's causing some negative effect.

Sustainable design is an issue of safety. Students value safety, but currently are not regarding sustainability as an issue of safety. This is an opportunity to shift thinking and use the resource of an emphasis on safety to understand sustainability in a new way. Much like how the conception of a product's cost needs to expand to include considerations of externalities, the idea of safety needs to be broadened to include concerns like quality of air and climate change. By clarifying that safety and sustainability are not separate entities, a new way of talking about sustainability could be approached. Safety is an existing value important to engineering, so adding sustainability to the concept creates a richer and deeper meaning of safety, thus using the resource of the value of safety to call attention to sustainability.

Suggestions for the Mechanical Engineering Program

This project was inspired by a need to bring more sustainability focus to mechanical engineering education. There was a call for a more theoretical approach to curriculum change (Fien, 2002; Thomas, 2004), and this study tried to address this change through using structuration theory and SAT. Identifying contradictions allows for interventions to be designed for specific locations within the organization. As discussed previously, large-scale contradictions at the macro-level seem daunting when thinking about change; however, small interventions at the organizational level are feasible and could have powerful impacts. The next section of this study will present a contradiction at the organizational level and corresponding interventions that could encourage more sustainability-based education. Additionally, the rules and resources available and needed to enact this intervention will be discussed. This is an opportunity to utilize structuration to create interventions informed by theory.

Contradiction: Class Design

Several contradictions could be addressed in designing classes in a different way**.** A contradiction to this whole issue is that the traditional way of educating mechanical engineers is being challenged by a need for new curriculum to prepare students for future careers. A different approach to teaching needs to be adopted to accommodate everything that must be learned in the confined 4 years allotted to undergraduate degrees. Also, sustainability education is addressed by hiring professors who specialize in sustainability. This specialization compartmentalizes sustainability education into classes taught by those specialists. Because “other professors have it covered,” professors who do not specialize in sustainability do not teach sustainability-focused concepts in their classes. This means the opportunity for students to learn about sustainability exists, but instead of being intertwined into multiple classes, it is sequestered into a boutique specialty. Both of these contradictions could be addressed by restructuring classes.

Intervention

I recommend making sustainability a small part of multiple classes offered in the department. Every class could utilize case studies, word problems, or examples that would discuss sustainability. This would serve a few purposes. First, it would expose students to concepts of sustainability and give them the opportunity to discuss these ideas and think about them in the context of other parts of their studies. In addition, it would communicate to the students that sustainable design is not a specialty concept; it is an important approach that should be woven through all aspects of design.

Rules and Resources

Incorporating ideas of sustainability into every class would be a valuable undertaking; some rules and resources would be needed to support the effort. Available currently are faculty who specialize in sustainable design and who could teach other professors about key concepts. Additionally, Mountain State University offers resources for teachers to incorporate into classes. A resource to be added would be time to create new sustainability-focused lessons. Throughout my interviews it became clear that professors were short on the resource of time; between researching, grant writing, and teaching, professors have plenty to do. The next resource that will be important is the knowledge in the subject. Many participants felt the subject was outside their area of expertise and were not comfortable teaching the subject matter.

The department has some rules and resources in place that will be useful when implementing this new way of approaching sustainability education. Mainly, most participants felt that sustainability is important knowledge for future engineers. Also, most individuals in this department care about the environment in their personal lives. The ABET requirements offer justification and guidance as to what to teach. Expanding the idea of engineer as problem solver to encompass ideas such as climate change and sustainable design is a way that the resource of identity could benefit new ways of teaching.

Perhaps a resource that could be provided would be one or two graduate students funded through the department. Their job would be to create one or two modules, lesson plans, or case studies that would fit into each class. They would meet with the lead professor of the class, discuss the need, and brainstorm what might be an effective way to bring sustainability into the coursework.

These teaching assistants would be a resource available to aid in the production of course content. They could come from the mechanical engineering department, or the department could hire a graduate student studying sustainability in another discipline. They would design the modules to be flexible so that they can be used for a few years before being updated. This would avoid burdening the professor with additional responsibilities, it would give a graduate student the opportunity to learn about curriculum design, and it would create easy-to-implement modules that would infuse ideas of sustainability into every class.

These modules should foreground concepts and words that engineers are comfortable with, like quality, savings, and safety. Many individuals I spoke to were wary of terms like environmental and sustainable. They felt these were fad words used to push an activist agenda. Emphasizing ideas more palatable to engineers, like externalities and long-lasting design, would allow sustainability concepts to be sold by their own merit and not be prejudged. Additionally, connecting these ideas with the upcoming trend of bioinspired design could offer some interesting places of exploration of how ecosystems work and how they could provide alternatives.

Contradiction: Professor Responsibilities

This is another suggestion that can address two contradictions. First, the retention, promotion, and tenure process (RPT) is important to professors as they progress in their careers; however, adding aspects of sustainability to their classes does not count toward the RPT process. Another contradiction that impacts RPT is the need for professors to acquire funding outside of the department through grants and still be effective teachers and researchers. Although it is unreasonable to assume that research and grant writing will cease to be foundational requirements for achieving tenure, perhaps the definition of work recognized by the RPT process could be expanded.

Intervention

Professors, especially those still trying to achieve tenure, already feel overwhelmed. Many mentioned in interviews that since creating lesson plans that build awareness of sustainability is not rewarded in the tenure process, it is not a priority. If the RPT process rewarded innovative ways of teaching sustainability, professors would have additional motivation to add sustainability to the curriculum. Additionally, I think this could be extended to all of the ABET requirements. Professors who consider those requirements while creating a class should be rewarded.

Rules and Resources

The RPT process could be used as a resource to motivate professors to teach in a new way. A change of the rules for earning tenure could serve as a motivator for professors to incorporate ideas of sustainability into classes. Aligning the RPT process with the already existing resource of ABET could help professors stay focused on the different aspects of engineering to be taught. Also, rethinking the identity of an engineer as a political actor poised to solve problems could help to bring professors and students to be more engaged with the intersection of social issues and engineering. By encouraging engineers to be social activists, a problem-solving attitude could be applied to a number of social issues, including environmental concerns, human labor in manufacturing, and accessibility for those with disabilities. There are already several students and professors within the department who could serve as examples in this process.

Contradiction: Reframing Ideas of Sustainability

Although the overwhelming majority of climate scientists agree that climate change is happening and is human-caused, within the department the issue is still being framed as a social or political problem instead of a scientific one.

Intervention

Climate change should be spoken about as a scientific fact. Presenting it as a component of the science that informs engineering—alongside physics and math—would change the framing of climate change. This way, sustainability can be addressed as directly linked to engineering, rather than as a peripheral social or political issue. For example, as I was working in a civil engineering class one summer, some students gave a presentation. A senior faculty member provided feedback after the presentation, recommending that the students consider climate change and how it would impact their design. He suggested that it was going to impose change on the roads and water systems. He spoke as if there were no doubt that it was happening and that engineers must adapt their way of thinking. It would be a great benefit to mechanical engineering if climate change were approached in this way by the department.

Rules and Resources

This would offer a resource to professors and students to talk about climate change in a new way. It could also draw upon the existing resource that many members of this community already recognize that climate change is a fact.

Incorporating ABET Requirements

The process of ABET accreditation is important to the department. However, its utilization within the department presents a contradiction. Instead of being seen as a resource in which professors can use the requirements as foundations to building classes, it is perceived as a nuisance when accreditation time comes around.

Intervention

The intervention recommended is to reframe ABET to be a resource or foundation for building classes. Utilizing ABET as a resource can guide professors to create engineering classes that will include knowledge and skills beyond physics and math. Rewards should be offered to professors who create classes by starting with the ABET criteria and deliberately incorporating these ideas into classes. Perhaps an auditing system could be implemented in which courses that do not address all of the criteria at some point in the semester could be penalized. The result will be new engineers that view themselves as problem solvers, communicators, and environmentalists.

Rules and Resources

ABET itself can be framed as both a rule and resource. Instead of viewing the accreditation as a constraint, it could be viewed as a resource to guide class content creation.

Innovative things are happening in the department around the concept of sustainability. However, my project indicates that the department would benefit from additional suggestions based in theory. They could help students explore these concepts in a way that will bring a more holistic and sustainable approach to the design process. The practical implications were made clear, and this serves as a case study that can be used in other organizations that need to socialize members in a new way in the face of climate change.

Theoretical Implications

Organizational change is a complex and multifaceted process. Change is hard, and when faced with daunting issues such as climate change it can feel overwhelming. Fien (2002) and Thomas (2004) call for a more theoretically based approach to implementing sustainability into the design process for engineers. This study offers such a theoretically driven approach. As stated in Chapter 2, often research recounting sustainability efforts focuses on describing an innovative program but lacks a theoretical approach to organizational change (Abdul-Wahab, Abdulraheem, & Hutchinson, 2003; Boyle, 2004; Bryce, 2004; Davidson et al., 2010; Desha, Hargroves, & Smith, 2009; Dincer & Rosen, 1999, 1999; Fenner, Ainger, Cruickshank, & Guthrie, 2005; Ferrer-Balas, 2004; Fox, Hundley, Cowan, Tabas, & Goodman, 2009; Hadjamberdiev, 2004; Hanning, Abelsson, Lundqvist, & Svanström, 2012; Lundholm, 2004; Mulder, Segalàs, & Ferrer-Balas, 2012; Nagel, Pappas, & Pierrakos, 2011; Pappas & Pierrakos, 2010; Paten, Palousis, Hargroves, & Smith, 2005; Peet, Mulder, & Bijma, 2004; Prins, Kander, Moore, Pappas, & Pierrakos, 2008; Rowley, Yelamarthi, & Bazzoli, 2008; Svanström et al., 2012). For this study, instead of a description of a program, structuration theory was used to identify contradictions. Foot (2001) describes contradictions as points within the organization that create hinges or opportunities for structures to be realigned. This study offers structuration and SAT as theoretical lenses in which to facilitate more sustainability education into engineering programs.

Contradictions Used in Organizational Change Processes

Within the context of climate change, new policies and actions have been difficult to achieve. Although the issue has been part of the public discourse for years, limited global action has occurred. How change occurs—especially the type of change needed to fundamentally alter the attitudes and actions toward global climate change—is currently misunderstood. This research, however, tries to frame organizational change as a new paradigm of inquiry wherein structuration and SAT, specifically the identification of contradictions at multiple societal levels, provides a means for detecting where fissures exist. These could provide organizational sites to host an opportunity for change. Additionally this study advocates the structuration concept of rules and resources to support efforts in change made at points of contradiction. Change initiatives observed within this organization failed because rules and resources were not identified and implemented to support the change effort. As discussed throughout this study, current efforts have repeatedly proven ineffective, and so new ways of facilitating change are needed. In this study, I argue that large-scale change could begin with micro-level actions within organizations. The hope is that these small-scale changes could eventually impact the macro-structures of society.

I have argued in this dissertation that large sweeping changes have yet to come to pass, so instead we turn to contradictions to identify sites for focused micro-changes at the organizational level. SAT provides an effective lens to examine contradictions and identify sites for change. Macro-level structural influences such as international treaties, federal and state governmental policies, funding bodies, and discipline-specific organizations provide rules and resources to enable and constrain mid-level and organizational change. In other words, they impact the ways organizations are structured. Since macro-structures affect organizations, it stands to reason that changes made at the organizational level could impact macro-level institutions.

On the organizational level, small changes are occurring, and sustainability is incrementally making its way into the socialization process of new engineers. New hires, course additions, and enthusiastic students are constantly enabling micro- changes, which over the course of time result in new and interesting reconfigurations of the rules and resources that evolutionarily change the entire structure. These newly configured organizations will socialize new engineers who will go on to be actors and decision makers in industry and other mid- and macro-level organizations. This socialization of "what an engineer looks like" that occurs before students enter the job market will shape much of how they identify themselves throughout their careers. If this socialization process includes new engineers being conscientious about sustainable design, the identity will impact the organizations and institutions in which they eventually are employed. Perhaps there is no better way to effect large-scale, immediate change than to do so at the level of the students now enrolled in our classes.

Identifying these contradictions within macro-, mid-, and micro-institutions could be viewed as searching for a source of dissonance. However, using contradictions as sites to begin change, micro-level change actions bring us back to the idea of obstacle-tunities. These obstacle-tunities are places of inconsistency within organizations that can be reimagined as having potential for growth and new formation of structures. SAT helps to recognize those contradictions so that obstacle-tunities have the chance to be transformational. This study extends and validates SAT (Canary, 2010a & 2010b) and introduces the theory into a new context.

Unfortunately, because of the unique nature of global climate change issues, evolutionary change is not an appropriate timescale in which to effect changes that are now happening in earnest. Instead, a reexamination of episodic change, particularly in the form of micro-changes, is now necessary in order to implement adjustments in strategic, organizational locations as a method for establishing a means of identification of contradictions using SAT. The combination of identifying contradictions, creating change actions around them, and identifying the rules and resources necessary for the changes to be successful is a promising approach to organizational change in the face of environmental calamity. Such interventions will go a long ways toward identifying contradictions as a way to stage interventions, which will result in a reconfiguration of the rules and resources needed to reverberate throughout systems and structures of large-scale change.

Environmental Communication

This study opens a few exciting areas of exploration for environmental communication. This study offers a case study of a specific organization that is faced with a change in how to socialize its employees. The use of structuration and the identification of contradictions at the micro-, mid-, and macro-levels allows for environmental communication to explore new realms of scholarship and apply it to real-world issues. This study implicates the process of socialization and the contradictions within this process of training new engineers. Through this type of study, environmental communication could help to develop interventions and communication processes for organizations struggling to change and adopt a more sustainable way of operating.

Although this organization understands that changes need to be incorporated to make sustainable design a larger part of the curriculum, it is difficult to critically analyze an organization of which you are a member. The engineers within this department may not be attuned to what I, as an organizational communication scholar, was able to discern. However, organizational communication theories provide the lens for scholars to act as ethnographic observers to identify contradictions, rules, and resources that could help facilitate change. This was effective within this case study and could be implemented in other organizations.

The other contribution to environmental communication is cloistered advocacy. A large challenge that this study uncovered is that people who are inclined to identify with values associated with environmentally conscious actions choose not to identify as environmentalists. Identifying cloistered advocacy opens a space for conversations around this. By offering more options than the binary of environmentalist or nonenvironmentalist, advocacy organizations might create tactics to inspire action from those who may not be persuaded by traditional forms of persuasion such as protests or media campaigns. Scholars can better understand resources available to organizations by identifying people who have some inclination to environmentalism while not embracing the label of environmentalist.

Limitations of the Study/Future Lines of Investigation

The first limitation of this study was that I was personally involved with many of the participants through teaching in the department. Although this involvement was a valuable resource, it also may have impacted the answers participants gave me. Because we had a relationship and because of the nature of the questions I was asking, they may have suspected what answers I wanted to hear.

Second, this case study was also an examination of one mechanical engineering department in one conservative state. Expanding the study to multiple programs in many geographical and sociopolitical regions may provide a broader view of this issue.

Third, this study was also limited by time. In a longer study, the interventions could be implemented and a measurement of their effectiveness could be taken.

In pursuing future lines of investigation, the next step is to enact the recommendations provided to the organization in this study. This will include applying the interventions and testing them for effectiveness. This could simultaneously further test the value of SAT by discovering whether interventions designed to address identified contradictions are indeed helpful. Additionally, to build more evidence of this concept of change, repeating this study as well as implementing its recommendations with another organization would help determine whether these findings are reproducible.

Conclusion

The challenges that climate change presents can feel overwhelming. Engineering schools have asked for a more theoretical approach to adopting ideas of sustainability in curriculum. This study offers a theoretical approach to implementing new concepts into departments. Organizational change is difficult, and it can feel discouraging that it is not happening quickly enough. This study offers hope for the future. Approaching change through structuration offers the process of identifying contradictions as precisely as possible (primary, secondary, tertiary, and quaternary), and identifying where they happen gives the chance to pinpoint where an intervention could occur within an organization that could resonate with a change that could impact larger institutions and systems. Additionally, identifying rules and resources that can be used in response to the contradiction allows the organization to plan what is needed to help enact change. Hopefully these findings can be applied to multiple organizations, changing the way organizational members are socialized to consider sustainability. This can be useful for not only academic organizations, but for any organization facing the challenges that climate change is going to offer the world.

Scientists and policy experts agree that climate change is forthcoming, yet macro-organizations are not creating policy to impact all levels of society. This study offers the use of structuration theory and SAT to create an understanding of contradictions and organizational change through the socialization of new engineers. System changes must consider how people experience contradictions and how they negotiate them. This will allow for productive change at the places within the system where contradictions exist.

APPENDIX A

STUDENT SURVEY

Please complete the following questionnaire to the best of your ability. If you do not have an answer to a question, leave it blank. Thank you.

Part 1. Demographics

Sex: Male Female

Age: __________

Class Standing: Freshman Sophomore Junior Senior

Engineering GPA:

Do you currently work/hold an internship? Yes No

What is your position?

Part 2. Design

What are five aspects of design you consider when beginning a design project?

1.

2.

3.

4.

5.

What does sustainable design mean to you?

Please list three concepts or ideas associated with sustainable design:

1.

2.

3.

Please list the 5 R's of environmentally conscious design:

1.

2.

3.

4.

5.

Please list the three elements of the Triple Bottom Line of Sustainable Design:

1.

2.

3.

What U of U classes have taught you about sustainability? *Please write NA if no classes have addressed sustainability.*

Have you learned about sustainability anywhere outside of the mechanical engineering department?

Yes No

Where:

To what extent do you think that ideas of sustainable design will be important in your role as a practicing engineer?

1	2	3	4	5	6	7
Not at all important						Very important

Please explain.

What is the relative importance of sustainability being a part of mechanical engineering practice in your decision to choose mechanical engineering as a career?

1 2 3 4 5 6 7
Not at all important Very important

Please explain.

To what level is sustainability important to you in your personal life?

1 2 3 4 5 6 7
Not at all important Very important

Please explain.

Do you think global climate change is happening?

1 2 3 4 5 6 7
1- No, no way
2- No, I do not think it is
3. No
4 It is probably not caused by human
5 I am not sure
6 I think it is
7 Without a doubt

Do you think global climate change is caused by humans?

1 2 3 4 5 6 7
No, I do not think it is Without a doubt

APPENDIX B

INTERVIEW QUESTIONS FOR MECHANICAL ENGINEERING STUDENT

The following is a guide that has been created to facilitate the interview process. As I meet each participant, I will work on building rapport with each individual to create a comfortable environment where each participant is open to speaking with me. These questions are not intended to confine the possibilities of each interview; rather, they will guide the process. I will be open to a flexible interview schedule and accept the prospect that each interview will be different. In addition to greeting them at the beginning of the interview, each participant will be informed that their names will changed in the research process, and information that could indicate or reveal their identity will not be used. For example, I will not use a direct quote that could identify the participant.

Introduction: Hello. My name is Maria Blevins and I am the primary investigator of this study. The purpose of this interview is to understand how you have been thinking and learning about sustainability in mechanical engineering. Your participation in this interview is voluntary and you are free to answer or not answer the questions.

General Questions: Tell me about how you decided to become a mechanical engineer.

What is your specialty or favorite aspect of mechanical engineering to study?

What do you see yourself doing in your career?

What have your favorite classes been so far?

What have been opportunities or experiences in the department that have helped you understand what your job as a mechanical engineer will be like?

How do you define sustainable design? Tell me everything you think about in sustainable design.

Follow up questions:

How does cradle to grave design fit into your idea of engineering?

How do you consider the carbon footprint of your designs?

Do you feel that sustainability is a foundation to your studies?

What things do you have to do in classes or labs to demonstrate sustainable design?

What textbooks have addressed issues of sustainability?

What do they say about sustainability?

How do your classes help you learn about these concepts?

Do you think there is a place in any of your classes that you could incorporate these ideas more?

What do you think about the concept of global climate change?

Follow up questions:

Do you think it is something that will affect your career?

How do you and your friends and family talk about it?

How is it spoken about in school?

How have your classes connected the ideas of sustainable design, global climate change, and engineering?

Tell me about how the skills you have learned in mechanical engineering fit into solving environmental issues?

Do you see advantages to engaging in sustainable design other than environmental ones?

Do you feel that you have been taught the skills necessary to incorporate ideas of sustainability into your designs?

Is the use of natural resources talked about in your classes?

I have no further questions. Do you have anything you would like to add?

Do you have any questions concerning the study?

Thank you for your time and willingness to participant

APPENDIX C

INTERVIEW QUESTIONS FOR MECHANICAL ENGINEERING INSTRUCTOR

Introduction: Hello. My name is Maria Blevins and I am the primary investigator of this study. The purpose of this interview is to understand how you have been thinking and teaching about sustainability in mechanical engineering. Your participation in this interview is voluntary and you are free to answer or not answer the questions.

General Questions: Tell me about how you have become an engineering professor.

What classes do you teach?

What is your research area?

Tell me about the ABET process.

Do you have thoughts about the ABET accreditation process? If need more prodding, do you think that the requirements are reasonable to educate engineers, are there any requirements you would get rid of?

ABET criteria states that students from accredited programs should be able to demonstrate an array of skills, two specifically, requirement c and h state:

> "(C) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
>
> (h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context " ("ABET accreditation," 2013, section, general requirement 3 student outcomes)"

How do you incorporate these concepts into your classes?

With limited class time, how do you prioritize the different aspects, science, math, design processes, and more systems aspects such as sustainability or environmental considerations?

Is it difficult to get it all in?What is the department's goal or stance on sustainability? Do you think it consistent with the ABET requirements?

How did the department make a decision about how to incorporate sustainability into the curriculum?

Is there disagreement about how to handle sustainability?

What are the challenges with incorporating sustainability into curriculum?

What does the future of mechanical engineering look like?

What challenges does the profession face?

How do you prepare your students for that?

Do you think energy and new ways of using natural resources is important?

Would you define sustainable design for me?

Is it an important concept?

Do you try to incorporate sustainable design into your classes?

If yes….
How do you try to incorporate sustainable design into your class?

What happens when you teach those concepts?

Is there anything that makes teaching these concepts difficult?

How does sustainable design fit into the profession of mechanical engineering?

What are the barriers to sustainable design?

How do you feel the mechanical engineering department as a whole or a culture approaches sustainable design and global climate change?

What resources does the department provide to you to help you incorporate sustainable design into classes?

Do you think the department could do anything to support your effort more?

Do you believe that human caused global climate change is happening?

Do you teach about it in your classes?

Do you see advantages to engaging in sustainable design other than environmental ones?

I have no further questions. Do you have anything you would like to add?

Do you have any questions concerning the study?

Thank you for your time and willingness to participate

APPENDIX D

INTERVIEW QUESTIONS FOR PRACTICING MECHANICAL ENGINEERS

Introduction: Hello. My name is Maria Blevins and I am the primary investigator of this study. The purpose of this interview is to understand how you have been thinking about sustainability in mechanical engineering. Your participation in this interview is voluntary and you are free to answer or not answer the questions.

General Questions: Tell me about how you have become an engineer?

Where do you work, what is your job like?

Tell me what prepared you for your engineering job best?

What do you wish you had learned more about in school?

What does the future of engineering look like?

What are the main challenges facing the field of mechanical engineering?

How do you define the concept of sustainable design?

Is it an important concept?

How does sustainable design fit into the profession of mechanical engineering?

How did you learn about it?

Do you seek more information about it, if so, how?

Can you think of an area in which the school you were trained as a mechanical engineer department could improve in teaching sustainability?

How do you see change to more sustainable design happening?

What keeps it from happening?

Do you try to incorporate sustainable design into work?

How do you try to incorporate sustainable design into your work?

What happens when you try to attempt to design in a more sustainable way?

What barriers exist to designing in a more sustainable way?

Does your workplace encourage sustainable design?

If so how?

Is there any way you could feel more supported in sustainable design?

Do you believe that human caused global climate change is happening?

Do you see advantages to engaging in sustainable design other than environmental ones?

I have no further questions. Do you have anything you would like to add?

Do you have any questions concerning the study?

Thank you for your time and willingness to participate.

APPENDIX E

INTERVIEW QUESTIONS FOR MECHANICAL ENGINEERING DEPARTMENT STAFF

Introduction: Hello. My name is Maria Blevins and I am the primary investigator of this study. The purpose of this interview is to understand how the mechanical engineering department is thinking and teaching about sustainability in mechanical engineering. Your participation in this interview is voluntary and you are free to answer or not answer the questions.

General Questions: Tell me about how you came to work here.

How would you describe this department?

What are your favorite things about working here?

Do you hear a lot of discussion about sustainability?

How often do you mention sustainability when talking to prospective students?

Do prospective students ask about it as they are considering the department?

How do students learn about sustainable design?

Are you aware of what sorts of classes are offered that teach about sustainability?

What professors teach classes or do research relating to sustainability?

Do you advise students that understanding sustainable design is an important concept?

What things happen in the department to encourage concepts of sustainability?

Can you think of an area that the department could improve in teaching sustainability?

What do you think about the concept of global climate change?

I have no further questions. Do you have anything you would like to add?

Do you have any questions concerning the study?

Thank you for your time and willingness to participant.

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